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CONTENTS

Systematic Changes in the Shoot Apex of Psilotum.
David W. Bierhorst 231

Embryology, Breeding Behavior and Morphological Characteristics of Apomictic, Triploid Rubus Idaeus L.
Charlotte Pratt, John Einset and Robert T. Clausen 242

Two New Eryngia (Umbelliferae) from Santa Catarina, South Brazil. ..... *Mildred E. Mathias and Lincoln Constance* 255

Cultivation in Vitro of Excised Endosperm and Meristem Tissues of Corn. ..... *Taiki Tamaoki and Arnold J. Ullstrup* 260

Torreya
Field Trip Reports. Book Reviews 273

Abbreviations of Titles of Serials Cited by Botanists.
Lasella Schwarten and Harold William Rickett 277

Index to American Botanical Literature 301

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BULLETIN OF THE TORREY BOTANICAL CLUB
VOL. 85, NO. 4, PP. 231–241 JULY, 1958

SYSTEMATIC CHANGES IN THE SHOOT APEX OF PSILOTUM[1]

DAVID W. BIERHORST

In addition to changes in morphology and histology and other changes related to ecological factors, rhizoid, sex organ, and appendage production, ramification, and possibly the presence of fungal mycelia, the shoot apex of *Psilotum nudum* (L.) Beauv. shows systematic changes in mitotic activity, cell and nuclear volume, and in frequency of nuclear aberrations. It is with these latter cytological variables and their relation to the origin of higher polyploidy, the limits of polyploidy, and the phylogeny of the Psilotaceae that the present paper is primarily concerned.

Methods and materials. The material used in this study was of the same race of *P. nudum* as used in previous investigations (Bierhorst 1953, 1954a, 1954b, 1954c, 1955, 1956), i.e., the University of Minnesota Greenhouse collection. The material was fixed in either FPA or CRAF V. Following standard dehydration and infiltration, it was sectioned at 12 μ and stained with either a combination of safranin and fast green, haematoxylin and fast green, or haematoxylin alone. Where material was used for comparing nuclear volumes, chromosome thicknesses, or spindle widths, care was taken to use only materials treated in identical fashion.

Morphology and histology of the apex. The apex in *P. nudum* has similar form in the gametophyte, the rhizome, and the aerial shoot (figs. 1–7). These apices have been described elsewhere (Bierhorst 1953, 1954b, 1954c). Briefly, a single apical cell exists throughout the life cycle of *Psilotum*. It becomes obscure or possibly absent in some of the gametophyte apices and smaller rhizomes. Adjacent to the apical cell are the cells of the prismatic layer. This layer is more pronounced in the aerial shoot apices. In the rhizome and gametophyte nearly equal, periclinal divisions occur in the superficial cells near the apical cell, resulting in a rather less distinct prismatic layer. Farther removed from the apical cell, the superficial cells are mostly isodiametric and divide predominately in the anticlinal plane. Periclinal divisions do, however, occur as long as the surface layer is meristematic.

Changes in the apex associated with the transition from rhizome to aerial shoot have been described elsewhere (Bierhorst 1954b). It should be mentioned here that the aerial shoot apex is capable of reverting back to a rhizome apex. This may occur if the apex is buried in soil before determina-

[1] This study was begun at the Samuel Miller Biological Laboratories of the University of Virginia.

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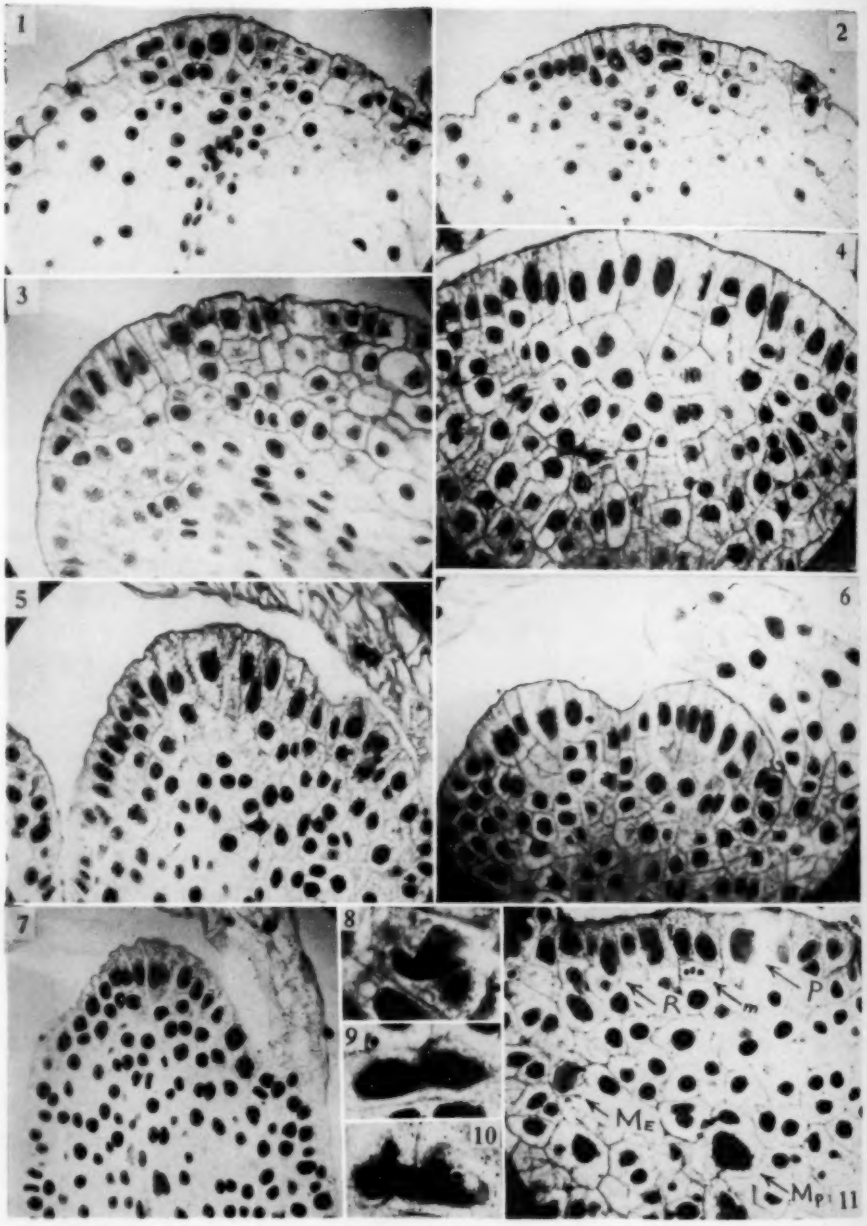


FIGS. 1–11. FIGS. 1–7. Longitudinal sections of shoot apices of *P. nudum* taken from different portions of the life cycle. FIG. 1, gametophyte, near median. FIG. 2, gametophyte, median. FIG. 3, rhizome, near median. FIG. 4, aerial shoot 0.5 cm above soil. FIG. 5, aerial shoot 6 cm above soil. FIG. 6, aerial shoot 9 cm above soil. FIG. 7, aerial shoot 30 cm above soil. FIGS. 8–10. Odd-shaped nuclei formed by the incomplete separation of daughter groups of chromosomes in an octaploid shoot apex. FIG. 11. Portion of an octoploid apex. Note: numerous micro-nuclei (m), multinucleate cells (m), dumbell-shaped nucleus in prismatic layer (R), large metaphase plate in polar view near center of figure (M_p), C-shaped metaphase plate in equatorial view toward left of center (M_E)). FIGS. 1–7, 11 are shown at the same magnification.

tion or cessation of apical growth. The transformation is slow in time, requiring several months. The production of appendages may continue, although sporadically, even after a typical, mature rhizome up to 1 cm in length is produced. The initial changes are increase in the diameter of the apex and axis produced, an increase in the proportion of ground meristem to procambuim, and the production of rhizoids. There are in addition cytological changes which will be described below.

Cytological changes. A casual examination and comparison of shoot apices of *Psilotum nudum* taken from different portions of the life cycle will show certain obvious cytological differences. Figures 1 to 7 are photomicrographs of shoot apices from different portions of the life cycle. All are shown at the same magnification. A comparison of figures 4 and 7 immediately makes it apparent that the apex of an aerial shoot 0.5 cm high has conspicuously larger cells and nuclei than one 30 cm high. Both were mitotically quite active at the time of fixation. The differences were put on a quantitative basis in the following manner.

Camera lucida outlines were made of interphase nuclei of the prismatic layer, of the surface layer 5 to 10 cells removed from the apical cell (henceforth referred to as protoderm[2]) where the cells are more or less isodiametric, and of the cells of the embryonic cortex 2 to 4 cells in from the protoderm (henceforth referred to as the inner cells). The drawings were made from 3 gametophyte apices, 3 rhizome apices, 4 aerial shoot apices approximately 0.5 cm above the soil level, 3 approximately 6 cm above the soil level, 3 approximately 9 cm above the soil level, 1 approximately 30 cm above the soil level, and one rhizome apex produced by reversion of an aerial shoot apex that was approximately 30 cm above the soil.

The volume of each nucleus could be calculated by using the formula: $V = 4/3\pi C^3 a^2 b$, where a is the minor axis on the drawing, b the major axis, and C the linear magnification factor. The use of the above formula is justified since the nuclei are circular in cross-section and ellipsoidal in longitudinal-section. Only the $a^2 b$ factor was used in the calculations since only relative volumes were of concern and in the computation of relative values the constants cancel out. The results are presented relative to the gametophyte as one. The average nuclear volume of the prismatic cells, protoderm cells, and inner cells of the gametophyte apex were arbitrarily set at unity and the corresponding volumes from the other apices were divided by the appropriate number.

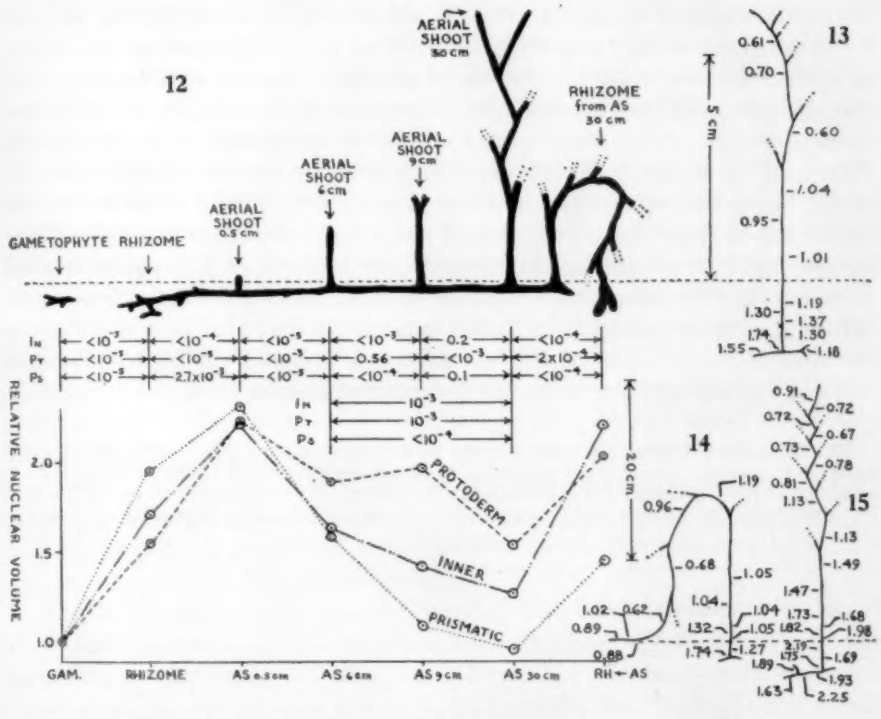
The results are presented in table 1. The Roman numerals across the top refer to the individual shoot apices of the gametophyte, rhizome, aerial shoot 0.5 cm high, etc. The letter N indicates the number of nuclei in the sample,

[2] Some objections will likely arise to the use of the term protoderm since some periclinal divisions occur in this meristem throughout its existence. The term here is a convenient tool and its application seems clear.

		GAM.			RHIZOME			AS 0.5 cm				AS 6 cm			AS 9 cm	AS 30 cm	RH-AS
		I	II	III	I	II	III	I	II	III	IV	I	II	III	I	I	I
INNER	N_s	20	20	20	20	20	20	25	25	25	25	20	20	20	20	20	22
	$\overline{X}_s$	0.93	1.04	1.02	1.56	1.75	1.81	2.17	2.11	2.09	2.48	1.58	1.56	1.78	1.42	1.27	2.20
	S_L		0.22			0.57				0.44			0.60		0.42	0.34	0.73
	$\overline{X}_L$		1.00			1.71				2.21			1.64		1.42	1.27	2.20
PROTODERM	N_s	20	22	20	20	20	20	25	25	25	25	20	20	20	21	20	21
	$\overline{X}_s$	0.97	0.93	1.09	1.29	1.87	1.50	2.18	2.21	1.94	2.59	1.96	1.66	2.05	1.97	1.53	2.03
	S_L		0.23			0.45				0.53			0.61		0.51	0.33	0.52
	$\overline{X}_L$		1.00			1.55				2.23			1.89		1.97	1.53	2.03
PRISMATIC	N_s	22	8	17	15	11	12	25	25	25	25	20	20	16	16	20	21
	$\overline{X}_s$	0.90	0.87	1.19	1.89	1.79	2.16	2.37	2.38	2.21	2.29	1.53	1.56	1.69	1.09	0.96	1.45
	S_L		0.40			0.63				0.63			0.36		0.25	0.25	0.40
	$\overline{X}_L$		1.00			1.95				2.31			1.59		1.09	0.96	1.45

TABLE 1. *Relative nuclear volumes in the shoot apex of P. nudum. Gam., gametophyte; AS, aerial shoot; RH-AS, rhizome produced from aerial shoot; N_s number of nuclei in individual apex samples; $\overline{X}_s$, average relative nuclear volume in the individual apex samples; S_L standard error of the large samples, i.e., all of the gametophyte apices or all of the rhizome apices, etc.; $\overline{X}_L$, average of the large samples.*

$\bar{X}$ the mean, and S the standard error. The means of the individual apex samples as well as the means for the 3 gametophyte apices, 3 rhizome apices, 4 aerial shoot apices 0.5 cm high, etc. are given. The probabilities indicative of significance between means (calculated from critical ratios) are shown as dimensions above the graph in figure 12.



FIGS. 12–15. FIG. 12. Changes in relative nuclear volume in the shoot apex of *P. nudum*. Diagram above graph shows morphological relationships among the apices plotted along the horizontal axis below. Probabilities indicative of significance between means are shown as dimensions. AS, aerial shoot; Rh-AS, rhizome derived from aerial shoot; In, inner; Pt, protoderm; Ps, prismatic. FIGS. 13–15. Diagrammatic representation of three mature aerial shoots of *P. nudum* with relative cross-sectional area per tracheid indicated at various levels. The broken lines indicate the soil level. Scale indication next to figure 14 applies to figure 15 as well.

In comparing the rhizome apex with the gametophyte apex, a near gigas relationship, i.e., 2/1, is apparent in the prismatic nuclei (1.95/1.00), somewhat less in the nuclei of the inner cells (1.71/1.00) and protoderm nuclei (1.55/1.00). One might expect a near perfect gigas relationship to exist between the nuclei of the rhizome apex and those of the gametophyte apex since they are very similar in morphology and environment and one is tetraploid while the other is diploid. However, the numerous instances of

apospory and apogamy which have been described in the literature (Manton 1950) not associated with changes in chromosome numbers indicate that the differences between sporophytes and gametophytes are reflections of more than differences in chromosome numbers and may be due to yet unknown physiological differences.

In following the sporophytic apex throughout the life cycle, definite and systematic changes in nuclear volume are seen to occur. Referring to table 1 and the graph in fig. 12, it will be noted that there is a pronounced increase in nuclear volume in all three areas of the shoot apex studied following the transformation of the rhizome apex into an aerial shoot apex. At this point in the life cycle, the nuclear volume is greatest (prismatic, 2.31; protoderm, 2.23; and inner, 2.21). Following this increase, there is a progressive decrease in nuclear volume as the aerial shoots grow, until a point is reached where the nuclear volumes in aerial shoot apex are close to those of the gametophyte. It should be emphasized here that all of the apices studied were mitotically quite active and showed no signs of change leading to determination or cessation of apical growth. It will also be noted that in the apex of the aerial shoot that reverted to a rhizome, the nuclear volumes increased to a level close to that of the other rhizome apices.

TABLE 2. *Comparison of relative nuclear volume among the three regions of the shoot apex of P. nudum. Gam., gametophyte; AS, aerial shoot; RH-AS, rhizome derived from aerial shoot; Ps, prismatic; Pt, protoderm; In, inner.*

	Ps/Pt	Pt/In	Ps/In
Gam.	1.9	1.0	1.9
Rhizome	2.4	0.9	2.2
AS 0.5 cm	2.0	1.0	2.0
AS 6 cm	1.6	1.2	1.8
AS 9 cm	1.0	1.4	1.4
AS 30 cm	1.2	1.2	1.4
RH-AS	1.3	0.9	1.2

Differences in nuclear volumes are also correlated with the area of the metaphase plate which in inner and protoderm cells averages 490 μ^2 in the aerial shoot apex 0.5 cm tall and 374 μ^2 in the one 30 cm tall and with metaphase chromosome thickness which ranges from 0.8 to 0.9 μ in AS30 and from 1.2 to 1.4 μ in AS0.5. This suggests that the extra nuclear bulk might be represented by raw materials for chromosome matrix, i.e., RNA.

Within the given samples, the volumes of the nuclei of the prismatic cells were consistently greater than those in the other two areas studied. The ratios of the prismatic to protoderm, etc. did vary and progressively so. The ratios within the given samples are shown in table 2. The ratios of the volume of prismatic to protoderm and prismatic to inner were approximately 2 in the gametophyte, rhizome, and young aerial shoot apices; then

these ratios became progressively smaller as the shoot became longer. No conspicuous increase in these ratios had taken place in the reverted aerial shoot at least up until the time it was fixed.

Some calculations of cell volumes were made. They were not so accurate as the nuclear volume results because of differences in shape between adjacent cells and between regions. The results did show, however, that changes in cell volume paralleled those of nuclear volume. The changes in cell volume are relatively clear in the photomicrographs in figure 1 to 7. It will also be noted that changes in cell shape are not conspicuous. Abbe, Phinney and Baer (1951) found no comparable changes in average cell size from plastochron to plastochron in maize.

Cell sizes in the differentiated tissues are reflective of those in the meristematic apex. One can readily observe, in cross-sections of stems at various levels, progressive reduction in cross-sectional areas of epidermal cells, cortical cells, and tracheids. Tracheids were chosen as representative and measured at various levels of three aerial shoots and intimately associated rhizomes. The results are given as relative cross-sectional area per tracheid in figures 13 to 15. Of the three aerial shoots chosen all were completely mature, one was relatively small (fig. 13), one was moderate in size (fig. 14), and one was relatively robust (fig. 15). Linear scales are shown next to the diagrams. At each level in each shoot, a camera lucida drawing was made of the xylem in cross-section. The drawings were made on a high grade paper with uniform weight per unit area. The drawings were cut out and weighed on an analytical balance, then the weight was divided by the number of tracheids in the cross-section.

It will be noted that there is a progressive decrease in the cross-sectional area per tracheid in the aerial shoot from the base to the apex with the maximum in each case near the ground level. The apparent excessive variability shown in the rhizome system is undoubtedly due to the fact that the number of tracheids is less and the number of tapering tracheid end walls one might encounter in the cross-section appreciably affects the final result.

In the shoot shown in figure 14 an appreciable increase in cross-sectional area per tracheid occurred toward the distal end. This shoot was bent over and the distal portion was lying prostrate on the soil surface for at least 2 months prior to complete apical differentiation.

The progressive decrease in cross-sectional area per tracheid parallels the progressive decrease in nuclear volume in the shoot apex. It obviously cannot be said that the tracheids shown in a cross-section of an aerial shoot at the ground level were produced directly from meristematic cells of the apex when it was just emerging from beneath the soil. There are a number of cell generations as well as cell elongation to account for. In reality, the tracheids at some higher level in the shoot, possibly 2 to 3 cm or more, would

be linear descendents several cell generations removed from the meristematic cells of the apex when it was just emerging.

Of 16 aerial shoot apices at or near the ground level examined (10 sectioned and 6 smeared) only 8 were observed to be essentially normal tetraploids with a 2n number of approximately 200. The 4 apices from which the nuclear volume data were collected were from this normal group. The other 8 were octoploids in whole or in part. Three of them were more or less entirely octoploid while 5 showed octoploid sectors. None of the apices more than 6 cm above the soil level showed any octoploidy. Octoploidy appears to originate rather frequently in this race of *Psilotum nudum*, but always results in the destruction of the meristem carrying it. It was observed over a period of several years that 1 to 3 percent of all the aerial shoot apices abort completely from 0–4 cm above the soil level.

An examination of a still active octoploid apex clearly shows the details of the course of self-destruction. During division in an octoploid cell with 400 or more chromosomes, conspicuous groups of chromosomes are not included in either of the two major daughter nuclei, if indeed the 2 major daughter nuclei themselves become separated. This results in a multinucleate condition with from 1 to 15 nuclei per cell (fig. 11) and with from 10 to well over 400 chromosomes per nucleus. The metaphase plate is often broader than the width of the cell and becomes C- or S-shaped (fig. 11). At anaphase, the two groups of chromosomes do not separate completely under such conditions and a single nucleus either U-shaped or dumbbell-shaped of a still higher polyploidy results (figs. 8–11). Following the establishment of the higher polyploidy, the mechanical difficulties encountered at mitosis are magnified beyond bounds and complete disorder results (fig. 11).

Cytological abnormalities, mostly in the form of multinucleate cells, were encountered only rarely in essentially normal apices in the gametophyte, rarely also in the rhizome, commonly in aerial shoots just emerging from the soil, rarely in aerial shoots up to 8 cm and never in higher apices. It should also be mentioned that meiosis was always observed to be normal despite the fact that Okabe (1929) and Barber (reported in Manton 1950) reported the occurrence of irregularities at this point in the life cycle.

Octoploidy has been observed several times after it had originated in tetraploid apices recently emerged from beneath the soil. In these instances, the new octoploid nuclei were U-shaped and resulted from incomplete separation of daughter groups of chromosomes.

It can be seen that in the shoot apices throughout the life cycle of *P. nudum*, the metaphase plate at mitosis occupies the greatest proportion of space available in those aerial shoot apices at or near the soil level, and in fact the plate frequently extends from wall to wall, especially in the prismatic layer. This is quite understandable in terms of nuclear (chromosomal) and cell volume. If cell shape remains relatively constant, as it appears to

do here, and cell volume increases, then cell cross-sectional area proportionately decreases. This is true since volume increases as the cube of the linear dimensions while cross-sectional area as the square of the linear dimensions. It is therefore understandable why octoploidy seems to originate at this point in the life cycle of the sporophyte due to incomplete separation of daughter groups of chromosomes. Once octoploidy has become established, the spacial relationships become so limiting that normal mitotic activity can no longer take place.

Discussion. It seems safe to conclude that tetraploidy in *P. nudum* represents the absolute end in this polyploid series and that spacial relationships in the very young aerial shoot apices are limiting to the establishment of high ploidy. *Tmesipteris* has apparently gone one step higher in the polyploid series with chromosomes numbers of well over 400 reported (Manton 1950, Barber 1954).

It is interesting to note that the sporangium is produced at that point in the life cycle of the sporophyte where nuclear and cell volumes are near minimum and nuclear aberrations fewest. It might be stimulating to speculate on the possible role of natural selection in placing it there. It is inconceivable that natural selection would fail to operate in such an instance. It seems probable that even now there is selective pressure to place more cell generations between that point in the life cycle where cell and nuclear volume are greatest and subsequent cytological instability exists and the initiation of sporogenous tissue. If this reasoning is followed still further, one might suggest that in the phylogeny of the Psilotaceae there has been a trend toward increasing the size of the sporophyte.

The tetraploid race of *Psilotum nudum* considered here is a stable and fertile one. The spores have been germinated (Bierhorst 1955) and the gametophytes have subsequently produced numerous embryos. Darnell-Smith (1918) similarly germinated spores of Australian material later determined to be tetraploid (Manton 1950). This race can hardly be considered a "raw", fertile polyploid of the type discussed by Stebbins (1950). There is nothing to suggest that there has been a progressive reduction in nuclear and cell volume over a number of generations resulting in a restoration of fertility as Wettstein (1937) demonstrated in *Bryum*. On the contrary, evidence seems to indicate that this has not taken place. If in an ancestral polyploid, nuclear volume was proportionately greater throughout the life cycle, a very pronounced cytological bottle-neck would have been present in those aerial shoots just emerging from the soil and normal vegetative as well as reproductive growth could not have been possible. The suggestion of Fagerlind (1944) that physiological adjustment resulting in increased fertility in polyploids can occur during the lifetime of an individual plant might well be adopted here. Certainly the statement is broad enough and all inclusive enough to cover those changes which occur in each aerial

shoot of *Psilotum*. The change would be concerned with the production of less chromosomal matrix material, i.e., RNA, and would be progressively expressed in older and older aerial shoots.

Randolph, Abbe, and Einset (1944) found a near perfect gigas relationship to exist between the shoot apices, but not between mature leaves, of diploid and tetraploid maize. They suggest: "A relatively simple explanation of this situation would be to assume that different genes belonging to the same genome, operating at different stages in the life cycle and responding differently to a reduplication of their number, are responsible for the observed differences in the effect of chromosome doubling on the shoot apex and on the mature leaf blade." The present study seems to indicate that increases in cell and nuclear volume might be a reflection of increases in the genetically inactive portions of the chromosomes rather than the genes themselves.

SUMMARY

1. Systematic changes in nuclear and cell volumes in the shoot apex of *Psilotum nudum* are described.

2. Nuclear and cell volume are maximum in aerial shoot apices just emerging from beneath the soil. This is correlated with the frequent origin of octoploidy which results in meristem abortion.

3. Sporangia are initiated in that portion of the life cycle where cell and nuclear volume are at a minimum and cytological stability is greatest.

4. From this study it has been suggested: a) that there has been a trend toward larger size of the sporophyte in the Psilotaceae; b) that tetraploidy ($4n \cong 200$) is the absolute end in the polyploid series for *P. nudum;* c) that there has not been a progressive phylogenetic reduction in cell and nuclear volume following origin of polyploidy in the Psilotaceae; and d) observed increases in cell and nuclear volumes in polyploids over their diploid predecessors may be due to an increase in the genetically inactive portion of the chromosome rather than to multiplication of the number of genes.

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EMBRYOLOGY, BREEDING BEHAVIOR AND MORPHOLOGICAL CHARACTERISTICS OF APOMICTIC, TRIPLOID RUBUS IDAEUS L.[1]

CHARLOTTE PRATT, JOHN EINSET AND ROBERT T. CLAUSEN

In the course of a survey of chromosome numbers in the genus *Rubus*, a colony of red raspberries growing wild in an area about three meters square on West Hill in Ithaca, N. Y., was pointed out to the second author by L. H. Bailey in 1945 and identified by the latter as *Rubus strigosus* Michx. Chromosome counts in root tips of three young plants from this patch showed them to be triploids with the somatic number of 21 (Einset 1947). Because of their proximity at the original site, their uniform chromosome number and their similar appearance, they were assumed, but not proved, to be a clone. For convenience in this paper, they will be designated as a single triploid form.

These triploid red raspberries were planted at the New York State Agricultural Experiment Station and a study was made of their breeding behavior. It was soon discovered that the majority of the seedlings produced after open-pollination were triploids like the maternal plant, which suggested an apomictic mode of reproduction. Further studies on the breeding behavior and embryology of the triploid were conducted to determine the nature and extent of apomixis in this form. In order to describe the apomict, characteristics used in taxonomic descriptions were scored for the triploid and for European and American red raspberries. In this paper the apomict will be first described and then its embryology and breeding behavior reported.

Description. The characteristics studied in 1953–1954 were drawn from the comparison made by Bailey (1945, pp. 866–867) of *Rubus idaeus* L. and *Rubus strigosus* Michx. For each plant studied, the prickliness and pubescence of one primocane were noted. Five observations per plant were made of each characteristic of the leaves, flowers and fruits. Samples of leaves of the primocanes included the lowest available leaf and the next four above that. For each of these, the following data were recorded: number of leaflets and length, width and pubescence of the dorsal surface of the terminal leaflet. Samples of leaves, flowers and fruits of the floricanes included one of each from each of the lowest five branches bearing flowers. Characteristics observed were prickliness and pubescence of the petiole of each leaf; total number of flowers, pubescence and length of the pedicel and pubescence of the calyx of the central flower of each cyme; direction

[1] Approved by the Director of the New York State Agricultural Experiment Station for publication as Journal Paper No. 1114, April 18, 1958.

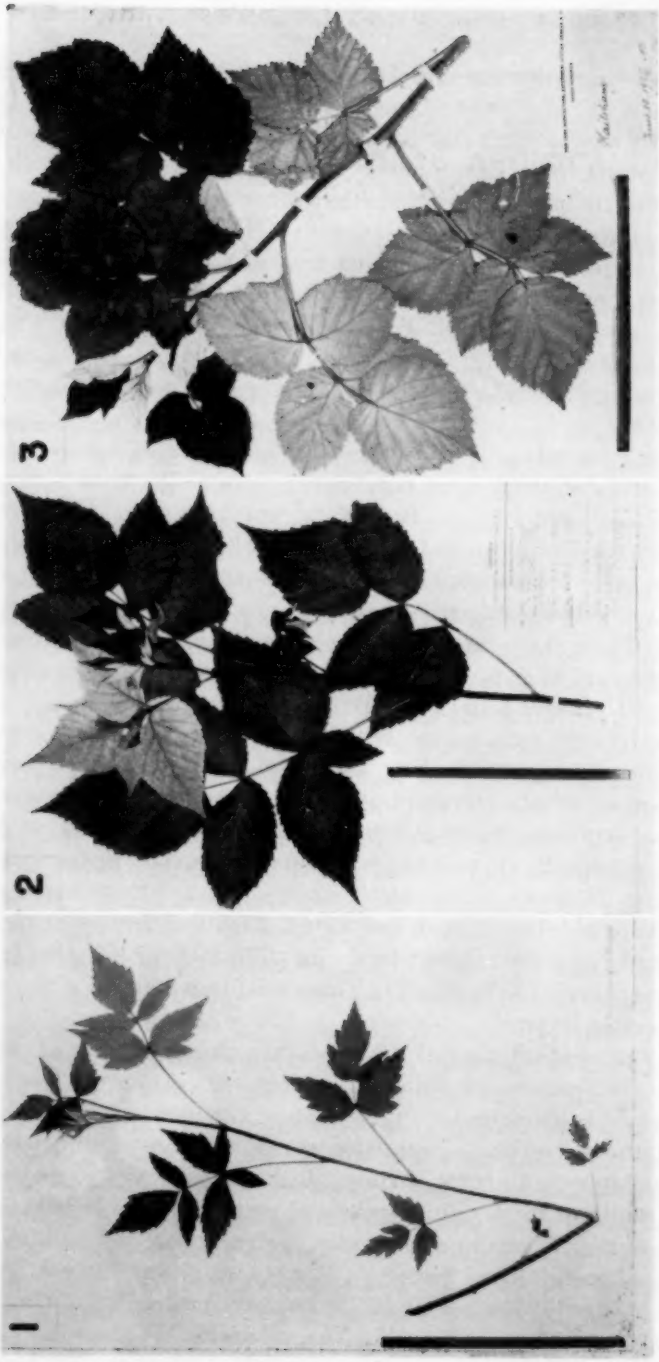
of the sepals at flowering and fruiting time; for each flower, the length and width of one sepal and of one petal, length of one filament and length and color of one anther; and for each ripe fruit, length and width of the fruit and of its torus, the number of drupelets, vertical diameter of one drupelet and the pubescence of the immature and mature drupelets.

Study of *Rubus idaeus* ssp. *strigosus* (Michx.) Focke (Clausen, 1949) was made of plants in the following locations in the state of New York: near a peat bog in the town of Waterloo (14 plants) (figs. 1, 4); in and near Bear Swamp, 3.5 km. NNE of Sempronius (five plants); in the ravine of Six Mile Creek, Ithaca (two plants). These plants were assumed to be diploid on the basis of chromosome counts and pollen measurements on similar plants.

No specimens of wild European *Rubus idaeus* L. subsp. *idaeus* were available, but for them were substituted twenty 28-chromosome seedlings (fig. 6) of Hailsham (fig. 3), an auto-tetraploid variety considered to have arisen from the European red raspberry (Bailey 1945, Thomas 1940). This population grew from seeds from open-pollinated flowers; in the absence of other tetraploid red raspberries these flowers were assumed to have been self-pollinated. These three- and four-year-old seedlings had been planted three decimeters apart in a row at the Geneva Station. They resembled the description of *R. idaeus* L. made by Bailey (1945).

The descriptive data for the triploid red raspberry were drawn from 48 triploid plants, grown at the New York State Agricultural Experiment Station at Geneva. Of the eleven plants which were derived vegetatively from the original triploids, six were growing in a crowded row in an eight-year-old planting (figs. 2, 5), and five were set three meters apart in a one-year-old planting. Nineteen three- and four-year-old seedlings had grown from seeds of the original stock open-pollinated. Eighteen three-year-old seedlings were derived from the original triploids pollinated with pollen from a diploid red raspberry (N.Y. 17861). These seedlings had been set three decimeters apart in a row.

Table 1 presents statistical data for some characteristics of the triploids and of the two subspecies with which they are compared. The number of plants studied is given under "n-plts." and the number of leaves or berries measured under "n-obs.". Regression coefficients (given under the heading "av.") and standard errors of these (listed under "s") are calculated for length on width of the terminal leaflets of primocanes, of berries and of tori. For the tori, the adjusted mean lengths (given under "av.") and the standard errors of these (listed under "s") are also given. The statistical methods of Snedecor (1957) are used. Underlined data indicate that there are no significant differences for that characteristic between the two groups of plants studied. One asterisk indicates significance at the 5% level and two asterisks significance at the 1% level.



FIGS. 1–3. Photographs of herbarium specimens of primocanes of *Rubus idaeus*. FIG. 1. *R. idaeus* subsp. *strigosus* (2×), Waterloo, N.Y. FIG. 2. *R. idaeus* (3×), N.Y.S. Agr. Exp. Station, Geneva, N.Y. FIG. 3. Hailsham (*R. idaeus* subsp. *idaeus*) (4×), N.Y.S. Agr. Expt. Station, Geneva, N.Y.

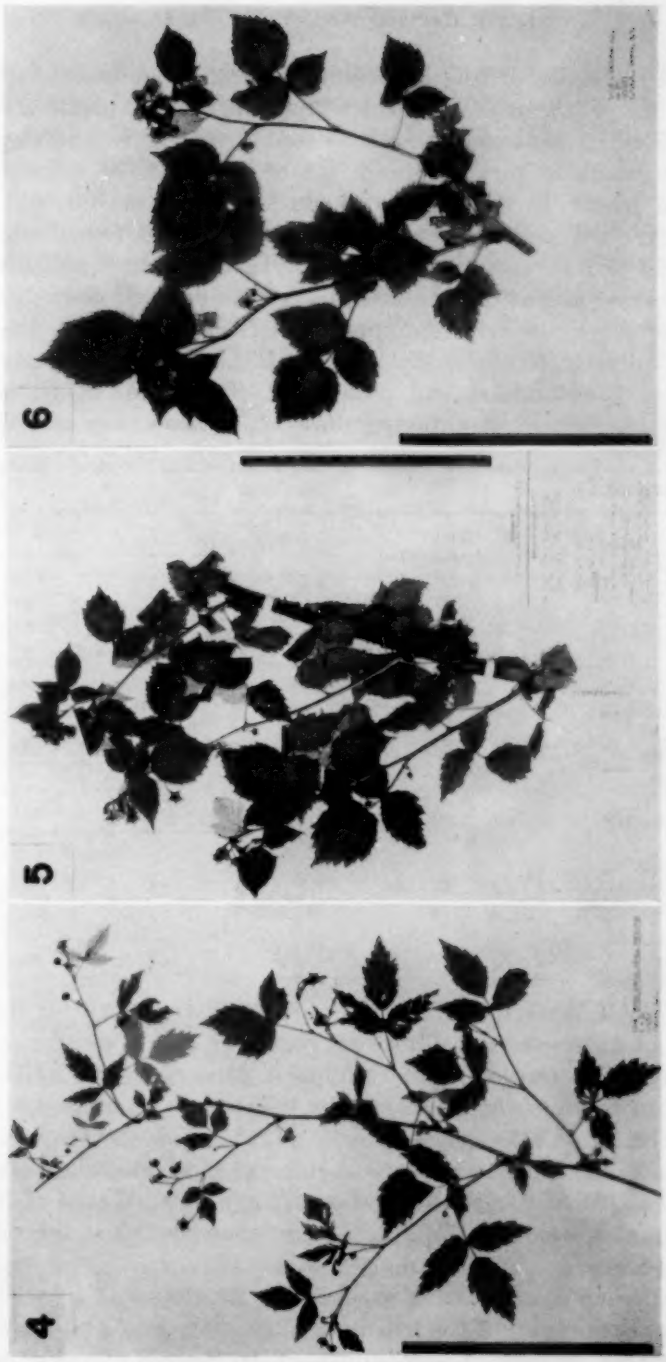


FIG. 4–6. Photographs of herbarium specimens of floricanes of *Rubus idaeus*. FIG. 4. *R. idaeus* subsp. *strigosus* (2×), Waterloo, N.Y. FIG. 5. *R. idaeus* (3×), N.Y.S. Agr. Expt. Station, Geneva, N.Y. FIG. 6. Tetraploid seedling of Hailsham (*R. idaeus* subsp. *idaeus*), N.Y.S. Agr. Expt. Station, Geneva, N.Y.

In the regression of length on width, both of the terminal leaflets of the leaves of the primocanes and of the berries, the triploid plants are more like *R. idaeus* ssp. *idaeus* than *R. idaeus* ssp. *strigosus*. In the regression of length on width of tori, no significant differences exist among the three groups of plants. In the adjusted mean lengths of the tori of the fruits, however, the triploids are very significantly different from both *R. idaeus* ssp. *idaeus* and *R. idaeus* ssp. *strigosus*. In the vesture and armature of the primocanes and of their leaflets, also of the petioles, pedicels and sepals of the floricanes, the triploids appear intermediate between the two subspecies. Generally, *R. idaeus* ssp. *strigosus* is glandular-hispid and *R. idaeus* ssp. *idaeus* is eglandular and puberulent. The sepals of *R. idaeus* ssp. *strigosus* are reflexed at anthesis; those of *R. idaeus* ssp. *idaeus* and the

TABLE 1. *Rubus idaeus—comparison of characteristics of triploid plants with those of two subspecies.*

	R. idaeus ssp. *strigosus* (2×)				Triploids				*R. idaeus* ssp. *idaeus* (4×)			
	n-plts.	n-obs.	av. (mm.)	s (mm.)	n-plts.	n-obs.	av. (mm.)	s (mm.)	n-plts.	n-obs.	av. (mm.)	s (mm.)
Terminal leaflets of primocanes—regression of length on width*	17	85	1.54	.11	36	180	1.10	.11	17	85	1.08	.12
Berries—regression of length on width*	12	60	.79	.09	21	105	.86	.20	12	60	1.34	.21
Tori—regression of length on width	14	70	.60	.64	17	85	.63	.23	13	65	.86	.64
Tori—length adjusted for regression**	14	70	4.20	.20	17	85	5.20	.10	13	65	7.70	.10

triploids simply spread; but the data are not satisfactory for tests of significance of difference, either for this character or for vesture.

Embryology. Ovules of the triploid raspberry grown at the Geneva Experiment Station were prepared for microscopic examination according to the procedure of Pratt and Einset (1955). The observations are presented in Table 2. For comparison, embryological material was collected from *Rubus idaeus* subsp. *strigosus* growing wild at Waterloo, N. Y., and from Milton, a diploid horticultural variety, cultivated at the Geneva Experiment Station.

In the brief description of embryo sac development in the apomictic triploid, only the basal of the two anatropous, unitegmic and crassinucellate ovules will be considered. The upper ovule became retarded during the early stages of sac growth and later degenerated. One to three sporogenous

cells derived from the multicellular archesporium enlarged and their nuclei entered prophase. One of these underwent an irregular meiosis and formed a tetrad, usually linear but occasionally T-shaped. The basal megaspore developed into a reduced, one-nucleate sac (fig. 7).

A sporogenous cell could develop into an embryo sac either directly or following a division, presumably mitotic. Only at the one-nucleate stage could such an aposporous sac be distinguished, by the absence of three degenerating megaspores, from a sac derived from a megaspore. As the sac enlarged the collapse of surrounding cells made the detection of megaspores impossible. Occasionally an aposporous sac and a tetrad were found in the same ovule (fig. 8).

TABLE 2. *Number of ovules of Rubus idaeus (3×) observed in stages of megagametogenesis or embryogeny.*

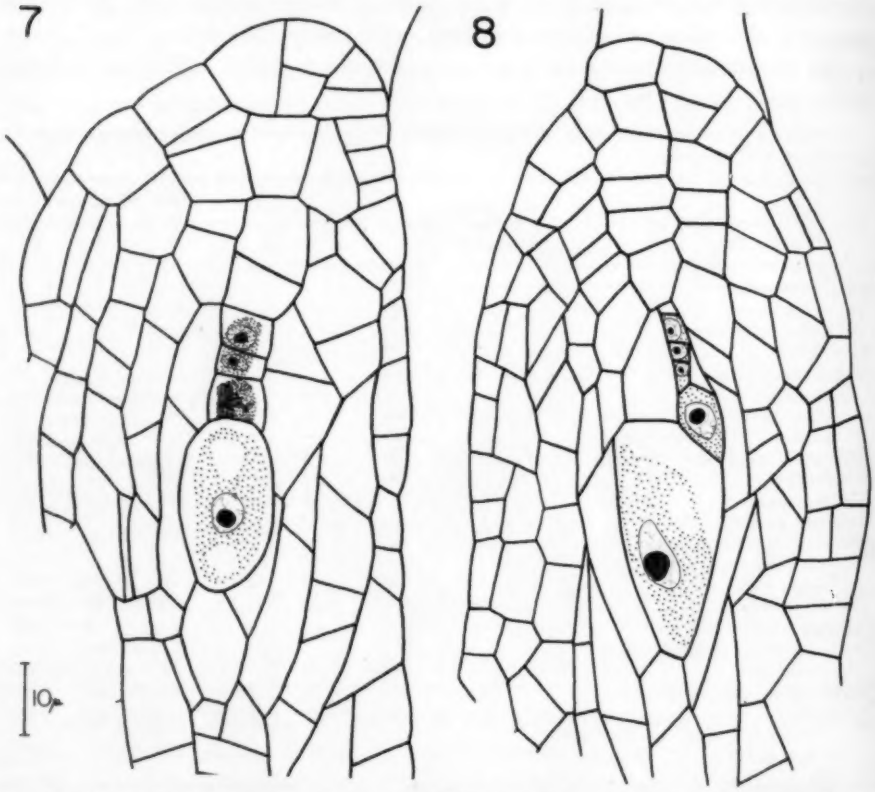
	5–1 days before bloom[1]	Bloom	Days after bloom				
			2	3	4	8	12
MMC—nucleus							
in prophase	13	—	—	—	—	—	—
in later meiosis	6	—	—	—	—	—	—
Tetrad	7	—	—	—	—	—	—
Single embryo sac							
One-nucleate	—	—	1	—	—	—	—
with three megaspores	9	—	—	—	—	—	—
without three megaspores	12	—	—	—	—	—	—
Two- to eight-nucleate	18	13	4	—	4	—	—
Mature	2	13	17	8	28	—	—
Abnormal	—	2	4	—	—	—	—
Multiple embryo sacs	1	2	2	1	2	1	—
Arrested sporogenous cells	—	1	1	—	2	—	—
Free-nuclear endosperm							
without embryo	—	—	6	12	4	—	—
with embryo	—	—	1	—	4–1[2]	12	1
Cellular endosperm	—	—	—	—	—	4	3
Ovule interior degenerating or collapsed	—	—	1	2	8	5	16
Total ovules observed	68	31	37	23	53	22	20

[1] Buds 2–6 mm. in diameter.
[2] See text.

Regardless of its mode of origin, an eight-nucleate embryo sac of the "normal" or "Polygonum" type (Maheshwari 1950) was formed. Multiple sacs (more than one sac per ovule) were occasionally found and these were often in widely different stages of development. At anthesis many sacs had not yet attained the stage designated in Table 2 as "mature", i.e., with egg, polar nuclei in contact or fused, synergids and antipodals degenerating. Some showed unusual numbers or arrangements of nuclei. Rarely, sporogenous cells did not develop further.

Fertilization was not observed. The division of the endosperm nucleus generally occurred before the division of the parthenogenetic egg or the zygote, but at later stages no close correlation was found between the num-

ber of cells in the embryo and the number of nuclei in the endosperm. For example, six ovules fixed two days after bloom contained an undivided egg or zygote and two to four endosperm nuclei, and one seed contained a five-celled embryo and six endosperm nuclei. However, one ovule with a two-celled embryo and polar nuclei in contact was found in material four days after anthesis. (This is the exceptional case indicated by footnote 2 in Table 2.) In ovules four days after anthesis two embryos of about 45–50 cells



FIGS. 7–8. Semi-diagrammatic camera lucida drawings of longisections of ovules of *Rubus idaeus* (3×). The micropylar end of the ovule is toward the top of the page. FIG. 7. One-nucleate sac developed from the basal of four megaspores (stippled). FIG. 8. One-nucleate aposporic sac and a tetrad with an enlarging megaspore (stippled).

were associated with endosperm of approximately 100–140 free nuclei, while an embryo of about 40 cells was associated with about 200 living and several disorganized endosperm nuclei. From the same lot, an embryo of 155–160 cells was found in one ovule with an endosperm of about 450 nuclei and in another seed with an endosperm of 300 nuclei. In general, more than 20 endosperm nuclei were found only in seeds with an embryo, and more than 250 endosperm nuclei were associated with embryos of more than 100

cells. The free nuclear endosperm formed a dense mass around the embryo, a less dense concentration at the antipodal end and a film along the sides of the large, irregular cavity in the nucellus. Wall formation in the endosperm began around the embryo, which then consisted of more than 200 cells. Frequently, the cells of the young embryo stained darkly and the structure of the nuclei was indefinite or lost. Such embryos were associated with unusually low numbers of endosperm nuclei and these sometimes appeared as darkly staining blobs. Probably such ovules did not mature.

Embryo sac development in two diploid red raspberries, *R. idaeus* subsp. *strigosus* and Milton, showed little or no tendency toward apospory. Observations on 23 young ovules of Milton revealed that 19 of them held tetrads of megaspores. In contrast to this, the examination of two lots of ovules of *R. idaeus* (3×) in which tetrads were the most frequent showed that only five out of 17 ovules had tetrads. No unreduced sacs were seen in either diploid. Multiple sacs occurred rarely in Milton, but were not found in *R. idaeus* subsp. *strigosus*. Ovules of the diploids developed more uniformly than those of the triploid. This is exemplified by the following data which may be compared with that for the triploid given in Table 2. At anthesis, all 24 ovules examined of *R. idaeus* subsp. *strigosus* contained mature sacs; 16 out of 17 ovules of Milton held sacs ready for fertilization. Two days after bloom 15 out of 21 seeds of Milton contained endosperm and three of these had young embryos. It is interesting to note that in the ovules of Milton two to four days after pollination the correlation between the number of cells in the zygote and the number of endosperm nuclei was no closer than that observed in the ovules of the triploid.

Fruit set. The degree of fruit set was figured as the percentage of carpels which developed into mature drupelets. The set of open-pollinated diploid Milton in 1951 was 58% and that of *R. idaeus* subsp. *idaeus* (4×) in 1953–1954 was 40%. Fruit set in the triploid red raspberry following open-pollination was rather low. On the average only 30% of the carpels of the triploid plants described in Table 1 matured, although occasionally a high percentage of them could develop. Counts of seeds from 76 fruits produced after open-pollination in 1948 and 1951 showed that 37% of the carpels matured. Following selfing in 1954 only 7% of the carpels developed. In emasculated, hand-pollinated flowers, the set was always lower than in intact flowers. With diploid red raspberry as the pollen parent the set was 13% (1949–1951), and with tetraploid red raspberry pollen 5% (1949–1951). The very low set of the latter crosses was possibly related to the often scanty pollen of Hailsham, the tetraploid red raspberry used. With blackberry pollen the set was variable. In 1954, fruit set was less than 1% when diploid or tetraploid blackberries were used as pollen parents, but in 1950–1952 16% set was obtained with pollen from diploids, in 1949–1951 15% set was induced by pollen from tetraploids. More than 350 flowers

emasculated but not pollinated set no drupelets (1949–1951), indicating that pollination is necessary for fruit set.

Chromosome numbers of seedlings. Seedlings of the triploid red raspberry were grown in the manner described by Einset (1951), except that the seeds were treated with H_2SO_4 for only 20 minutes instead of 30–60 minutes. The percentage of germinating seeds ranged from 0–100% but the average for all lots was 21%. Chromosome counts made in root tips of seedlings sufficiently vigorous to yield roots are presented in Table 3.

TABLE 3. *Rubus idaeus* (3×)—*somatic chromosome numbers of seedlings.*

Parents	Chromosome numbers of seedlings										
	14	15	19	21	25	26	27	28	29	35	Total
3× open-pollinated (1947–1950)	17	1	—	284	—	—	—	19	—	1	322
3× selfed (1950–1951)	3	—	—	3	1	1	3	—	—	1	12
3× X 2× red raspberry (1948–1950)	14	2	1	59	—	—	—	—	—	1	77
3× X 4× red raspberry (1949–1950)	—	—	—	—	—	1	2	54	1	—	58
3× X 2× blackberry (1950–1952)	3	—	—	38	—	—	—	—	—	—	41
3× X 4× blackberry (1950–1952)	1	—	—	1	—	—	—	20	—	—	22
Total	38	3	1	385	1	2	5	93	1	3	532

Eighty-eight per cent of the seedlings of open-pollinated origin and 77% of the seedlings having a diploid red raspberry as the male parent were triploid. Nearly all of these resembled raspberries and were assumed to have arisen from the parthenogenetic development of an unreduced egg. However, a seedling of *R. idaeus* (3×) X a tetraploid blackberry (Eldorado) possessed approximately 21 chromosomes and was hybrid in character. That unreduced eggs were also capable of development following fertilization by a 14-chromosome gamete from a 14- or 21-chromosome red raspberry was suggested by three 35-chromosome raspberry-type seedlings.

The functioning of gametes resulting from the irregular distribution of chromosomes in meiosis was indicated by the chromosome numbers of the small population of progeny from triploid *R. idaeus* self-pollinated. The 14-chromosome seedlings may have arisen from a parthenogenetic 14-chromosome egg or from the union of two 7-chromosome gametes. Evidence for the former hypothesis was found in a seedling of *R. idaeus* (3×) X a tetraploid blackberry (Erie) which was diploid and of the raspberry type. Other 14-chromosome seedlings died before their mature characteristics

could be noted. Diploid seedlings occurred more frequently when the triploid was pollinated by a diploid than when the pollen parent was tetraploid (Table 3). This suggests that some of the 14-chromosome seedlings were the result of fertilization rather than of the development of a parthenogenetic egg. The relation between the kind of pollen used and the development of endosperm has not been explored. The 15- and 19-chromosome seedlings may have developed from a parthenogenetic egg resulting from an irregular reduction division or from syngamy involving one or both aneuploid gametes.

The 28-chromosome combination appeared frequently and made up the majority of the progeny resulting from pollination by a 28-chromosome *Rubus*. This surprising result was obtained repeatedly. Recheck of the chromosome number of the maternal plants confirmed their triploid condition. If tetraploid *Rubi* are assumed to produce mostly 14-chromosome sperm, it would be expected that most of these 28-chromosome seedlings were the result of the union of two 14-chromosome gametes. Although it is not known if these tetraploid seedlings developed from the union of two 14-chromosome gametes, of a 21-chromosome female and a 7-chromosome male gamete, or of two gametes with aneuploid numbers, tetraploidy appeared to afford the seedlings sufficient vitality that many of them grew enough to provide root tips for chromosome counts. Thus, the ratio of 28-chromosome seedlings to total surviving seedlings may be higher than the original frequency of tetraploid zygotes, due to the failure of zygotes with other chromosome numbers. Most of the 28-chromosome seedlings of *R. idaeus* (3×) X blackberry (4×) died in their first or second year and their characteristics were not noted. Six of the tetraploid seedlings, however, survived longer, and showed characteristics of both the raspberry and the blackberry, and were undoubtedly hybrids.

Discussion. The present cytological studies on *R. idaeus* (3×) fit into and extend the pattern of diversity outlined in earlier work on European and American red raspberries. Chromosome counts in European red raspberries, both the wild forms (Christen 1952, Vaarama 1939) and horticultural varieties (Crane and Darlington 1927) have shown them to be diploid except for a few triploid and tetraploid varieties (Crane 1935, Petrov 1939) and eight experimentally produced triploids (Lewis 1939). Raspberries found growing wild in North America have been reported to be diploid (Longley 1924; Longley and Darrow 1924; Fischer, Darrow and Waldo 1940), except for the triploid plants found by Einset (1947). A few triploid and tetraploid horticultural varieties and hybrids were listed by the American workers Longley and Darrow (1924), Fischer, Darrow and Perlmutter (1943) and Britton and Hull (1957). The diploids were reported to reproduce sexually (Gustafsson 1947) and one triploid variety was shown to be pseudogamous by Petrov in 1939.

The only previous work on the development of the embryo sac in red raspberry known to the authors has been the paper of Christen (1952). His observations of embryo sac formation in a wild diploid *R. idaeus* collected in Switzerland are similar to those made on the present material, except that no instance of more than one meiotic division or tetrad per ovule was seen by the present authors.

Breeding data had shown that facultative pseudogamy existed in the triploid variety "Immer Tragende" (Petrov 1939). The author concluded that unreduced eggs were capable of developing into viable embryos either with or without fertilization. No study of the early stages of embryo sac formation was made.

The pattern of facultative apospory in *R. idaeus* (3×) is similar to that of triploid blackberries (Christen 1950, Pratt and Einset 1955). Features of this pattern common in apomictic plants are the infrequency of tetrads of megaspores, the occurrence of young embryo sacs unaccompanied by three degenerating megaspores, a wide range of developmental stages in ovules of similar age, and the presence of more than one embryo sac per ovule. The frequency of maternal seedlings varied among the triploid *Rubi* studied. A comparison of Table 3 in the present paper with Table 1 in Einset's account of apomixis in blackberries (1951) shows that *R. idaeus* (3×) produced 385 21-chromosome seedlings, or 72% of the total progenies, while the triploid blackberries produced 585 triploid seedlings, or 93% of the total offspring. Parthenogenetic development of an unreduced egg appeared more frequently among the blackberries studied than in the triploid red raspberry. As in the blackberries, the fruit set of apomictic triploids was lower than that of diploid sexual plants. Conditions associated with seed failure included the immaturity, abnormality or death of the sac at the time of bloom, breakdown of the nucellus or endosperm at various periods and the retardation and death of the embryo.

A hypothesis for the origin of the triploid red raspberry under discussion is suggested by the fact that it resembles both *R. idaeus* subsp. *idaeus* and *R. idaeus* subsp. *strigosus*. The interfertility of the American and European red raspberries has been indicated in horticultural literature on the basis of comparative morphology and the history of some varieties (Darrow 1920) or on current breeding work (Slate 1948). The complex, often unknown, heredity of the parent varieties makes these data difficult to interpret. Apparently, no attempts to cross typical members of the two subspecies have been reported. It is suggested that the present triploid arose from the union of a 14-chromosome gamete of a red raspberry of one subspecies and a 7-chromosome gamete from the other. The functioning of unreduced gametes in diploid red raspberries has been hypothesized by Lewis (1939) and Thomas (1940) to account for other triploids. Recessive or partially recessive genes for apospory and pseudogamy may have been

present which reached fuller expression in the triploid progeny (Gustafsson 1947).

SUMMARY

1. A triploid red raspberry, growing wild at Ithaca, New York, is intermediate in its gross morphology between *Rubus idaeus* subsp. *idaeus*, as represented by the autotetraploid variety Hailsham, and *R. idaeus* subsp. *strigosus*, as illustrated in wild plants of central New York.

2. Aposporous and reduced embryo sacs were found and pseudogamy demonstrated in breeding experiments.

3. The chromosome numbers of the offspring suggest that unreduced eggs functioned parthenogenetically (in 78–92% of the seedling populations) or following fertilization. Reduced eggs of various chromosome numbers functioned after fertilization and possibly parthenogenetically.

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TWO NEW ERYNGIA (UMBELLIFERAE) FROM SANTA CATARINA, SOUTH BRAZIL

MILDRED E. MATHIAS AND LINCOLN CONSTANCE

In the handsome set of some six dozen Umbelliferae collected last year in Santa Catarina, South Brazil, by Dr. Lyman B. Smith, Curator of the Division of Phanerogams of the United States National Museum, and his Brazilian companions, Padre Raulino Reitz and R. Klein, there are two species of *Eryngium* that appear to be quite distinct from any of the more than fifty species of this genus recorded hitherto from that country. Both, according to Dr. Smith, are "from localities which have provided new species" in other families.

Eryngium Reitzii, sp. nov. (fig. 1). Plantae perennes subscaposae 35–55 cm. altae, e radicibus fibrosis fasciculatis, caulibus solitariis, 30–50 cm. altis; folia basalia subcoriacea rosulata lanceolata, 3–14 cm. longa, 0.8–2 cm. lata, acuta, spinuloso-serrata, venis parallelis ad marginem versus manifeste divergentibus et anastomosantibus instructis, vagina haud dilatata quam lamina breviore; inflorescentia terminalis capitulis paucis, prophyllis duobus lineari-lanceolatis spinoso-serratis; capitula colorata cylindracea, 10–20 mm. longa, 7–10 mm. lata; bracteae involucrales 3–6, ovato-lanceolatae acutae integerrimae, 1.5–2.5 mm. longae, 1 mm. latae, quam capitulae breviores; bracteae florales eis involucralibus similes, fructibus breviores vel eos aequantes; coma deficiens; sepala ovata obtusa, 1.2 mm. longa; petala ca. 1.5 mm. longa, apice integerrimo instructa; styli ca. 1.2 mm. longi, sepala aequantes; fructus cuneato-ovoideus diametro 2.5–3 mm.; mericarpia papillibus vesciculosis ovatis toto dorsa valde convexo dense obsita.

Subscapose perennials 35–55 cm. tall from a fascicle of fibrous roots, the flowering stems solitary, 30–50 cm. tall; basal leaves subcoriaceous, rosulate, lanceolate, 3–14 cm. long, 0.8–2 cm. broad, acute, finely spinulose-serrate, the venation parallel in the central area, diverging and anastomosing toward the margins, the sheath scarcely dilated, much shorter than the blade; inflorescence of a terminal peduncle and usually 2 lateral branches subtended by a pair of linear-lanceolate, spinose-serrate bracts, each lateral branch bearing a pair of entire linear bractlets and usually a very much reduced lateral peduncle with a diminutive head in addition to the dominant terminal one; heads apparently bluish, cylindrical, 10–20 mm. long, 7–10 mm. broad; involucral bracts 3–6, ovate-lanceolate, acute, entire, 1.5–2.5 mm. long, 1 mm. broad, much shorter than the heads; bractlets like the bracts, shorter than to equaling the fruit; coma wanting; sepals ovate, obtuse, ca. 1.2 mm. long; petals ca. 1.5 mm. long, the apex shortly incurved, entire; styles about 1.2 mm. long, equaling the sepals; fruit cuneate-ovoid, 2.5–3 mm. in diameter, densely covered with ovate, vesicular papillae.

TYPE: *Smith & Reitz 10336*, "Mun. Bom Retiro: bog and pasture, by Fazenda Santa Antônio, Campo dos Padres, alt. ca. 1650 m.," Santa Catarina, Brazil, 23 January 1957 (UC 1,085,147; US). Another collection, also from Santa Catarina, but with narrower and doubly spinulose leaves.

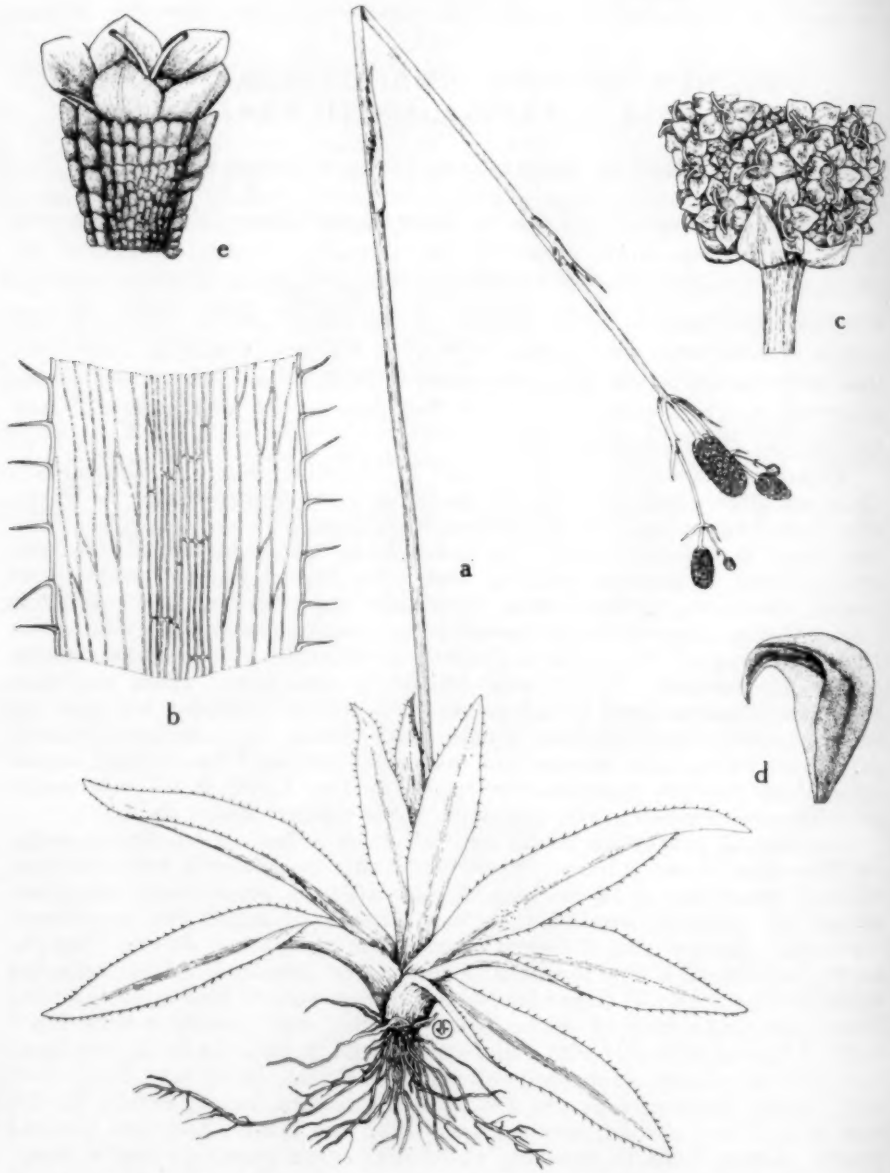

Fig. 1. *Eryngium Reitzii*. a. Habit, × ½. b. Leaf venation, × 2. c. Basal portion of a fruiting head, × 3. d. Petal, × 30. e. Mature fruit, with sepals, styles, and fruit papillae, × 8. (All from the type specimen.)

is *Smith & Reitz 10141,* "Mun. São Joaquim: campo, source of Rio Capivaras, Serra do Oratório, 10 km. east of Bom Jardim da Serra (Cambajuva), alt. ca. 1200 m.," 16 January 1957 (UC, US).

The distinctive venation, consisting of a well defined central zone of essentially parallel veins which diverge and anastomose toward the margins, and the "reduced," few-headed inflorescence permit placement of *E. Reitzii* in Section XXVII. Sanguisorbiformis H. Wolff (*in* Das Pflanzenr. 4^{228}: 208–213. 1913.), but the cylindrical heads exclude it from either of that author's two subsections. Its affinities are probably with *E. ciliatum* Cham. & Schlecht., *E. plantaginifolium* H. Wolff, and *E. Sanguisorba* Cham. & Schlecht., from all of which it is sharply distinct in leaf shape and margin, the broader and obtuse sepals, and the nature of the fruit covering.

Eryngium corallinum, sp. nov. (fig. 2). Plantae perennes humiles subscaposae, 20–25 cm. altae, e radicibus fibrosis fasciculatis, caulibus 1 vel 2, 15–20 cm. altis; folia basalia subcoriacea rosulata lineari-oblanceolata, 4–6 cm. longa, 0.2–0.5 cm. lata, lobis divergentibus, spinoso-pinnatifida, venis pinnatis, vagina infere dilatata quam lamina breviore, marginibus scariosis ad apicem versus ciliatis; inflorescentia terminalis, capitulis paucis, prophyllis 2 vel pluribus, foliis similibus; capitula viridia globoso-ovoidea, 7–10 mm. longa, 6–8 mm. lata; bracteae involucrales ca. 5, lineari-lanceolatae, integerrimae, 2–5 mm. longae, 0.5–0.7 mm. latae, quam capitula breviores; bracteae florales bracteis involucralibus similes, fructibus brevires, coma deficiens; sepala lanceolata acuminata, 1.5 mm. longa; petala viridia, 1.5–1.8 mm. longa, apice fimbriato instructa; styli quam sepala longiores; fructus globoso-ovoideus diametro 1.5–2 mm.. mericarpia papillis cylindraceoconicis acutis scaberulis inter se subaequalibus toto dorso valde convexa obsita.

Low, subscapose perennials 20–25 cm. tall from a fascicle of fibrous roots, the flowering stems 1 or 2, 15–20 cm. tall; basal leaves subcoriaceous, rosulate, linear-oblanceolate, 4–6 cm. long, 0.2–0.5 cm. broad, pinnatifid with spinose, divergent lobes, the venation pinnate, the short scarious-margined sheath dilated below, ciliate toward apex, much shorter than the blade; inflorescence of a terminal peduncle and 2 or 3 lateral branches subtended by a whorl of 2 to several leaf-like bracts, each lateral branch with or without a pair of bractlets; heads greenish, globose-ovoid, 7–10 mm. long, 6–8 mm. broad; involucral bracts about 5, linear-lanceolate, entire, 2–5 mm. long, 0.5–0.7 mm. long, much shorter than the heads; bractlets like the bracts, shorter than the fruit; coma wanting; sepals lanceolate, acuminate, 1.5 mm. long; petals greenish, 1.5–1.8 mm. long, the apex incurved and fimbriate; styles a little longer than the sepals; fruit globose-ovoid, 1.5–2 mm. in diameter, densely covered with cylindrical, tapering, roughened, subequal papillae longer than the width of the fruit.

TYPE: *Smith & Klein 11537*, "Mun. Chapecó: rocky barren, 9 km. west of Campo Er[illegible] alt. 900–1000 m.," Santa Catarina, Brazil, 20 February 1957 (UC 1.085,148; US).

This species is referable to Section XXVI. Foetida H. Wolff (op. cit., pp. 200–208.) and is closest to *Eryngium Ramboanum* Mathias & Constance (Bull. Torrey Club 81: 215–217, *fig. 1.* 1954.) from Rio Grande do Sul. Evident similarities are in habit, form of inflorescence, shape of the relatively few-flowered heads, and the remarkably fimbriate petals. It differs in its narrower and pinnatifid rather than merely spinulose-serrate leaves,

FIG. 2. *Eryngium corallinum*. a. Habit, × ½. b. Basal leaf, × 2. c. Head, × 3. d. Petal, lateral view, × 30. e. Same, front view, × 30. f. Semi-mature fruit, with sepals, petals, styles, and fruit papillae, × 10. g. Mature carpel, from commissural face, showing sepals, style, and papillae, × 8. h. Papilla, × 40. (All from the type specimen.)

more slender stems and peduncles, narrower bracts, bractlets, and sepals, and the more slender fruit papillae.

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CULTIVATION IN VITRO OF EXCISED ENDOSPERM AND MERISTEM TISSUES OF CORN[1]

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The continuous culture of corn endosperm *in vitro* was first accomplished by LaRue (1949). Pieczur (1952) also reported successful culture of excised corn endosperm. Straus and LaRue (1954), and Straus (1954) published detailed studies of the cultural requirements for and of the morphology and cytology of the original tissue (CE Clone 1-C) isolated by LaRue (1949). Straus and LaRue employed a modified White's medium containing 2 percent sucrose and 0.5 percent Seitz filter-sterilized yeast extract. With this medium they cultured the endosperm of two sugary varieties and of CE Clone 1-C successfully. The latter tissue was of undetermined genetic origin, but grew at a rate ten times greater than that of the two sugary varieties.

The objective of the present investigation was to establish tissue cultures of corn endosperm and meristem for ultimate use in corn pathology.

Material and methods. The test corn plants from which tissues were excised were of the sugary, starchy, waxy, floury, brittle, and pop types, and were grown either in the greenhouse or in the field.

For the cultivation of endosperm tissue, young ears (5 to 30 days post-pollination) were husked and surface sterilized with either 70 percent alcohol or 2.5 percent calcium hypochlorite, and then rinsed thoroughly with sterile water. The upper part of the endosperm was then scooped out with a small sterile scalpel and placed on the medium.

For the cultivation of meristem tissue, young corn plants (about 2.5 feet high) were cut at the base and the outer leaves were stripped off. The young shoots were surface-sterilized with 70 percent alcohol, split longitudinally, and explants were removed from the sterile interior. In order to obtain uniform explants, a glass tube with a sharp edge was used. Tubes of different diameters provided explants of different sizes. The size of explant most frequently used was 1 mm. in diameter, 1 to 2 mm. in length, weighed 3 to 5 mg., and contained about two-thirds nodal and one-third internodal

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tissues with a layer of intercalary meristem tissue between them. Various sizes of explants also were isolated from nodes and internodes, and some relatively large explants containing more than two nodes were tested.

Culture media tried were those of White (1943), Hildebrandt (Hildebrandt, Riker & Duggar 1946), Gautheret (White 1954), Henderson, Durrell & Bonner 1952), Heller (1953), and Nitsch (1951). These media were made up as prescribed by their respective originators with the exception that all contained 2 percent sucrose and 0.8 percent agar. In all cases 20 ml. of medium were added to each 50 ml. flask, and autoclaved at 15 lb. for 15 minutes. The pH of the media was adjusted to 6.0 before autoclaving.

Growth substances, i.e., indoleacetic acid (IAA), naphtholeneacetic acid (NAA), 2,4-dichlorophenoxyacetic acid (2,4-D), gibberellic acid, and kinetin, when used, were sterilized by filtration and added aseptically to the media just before solidification. Yeast extract and coconut milk were sterilized by autoclaving unless otherwise indicated. Tomato juice was prepared by filtering whole canned tomatoes through cheesecloth and centrifuging the filtrate before autoclaving with the media.

Results. Comparison of media. The 5 kinds of media listed in Table 1

TABLE 1. *Growth response of excised corn endosperm on various media.*

Media	Growth Response
White's medium	–
White's medium + tomato juice (20% by volume)	±
White's medium + yeast extract (2 g./l.)	+
Hildebrandt's medium	–
Hildebrandt's medium + adenine + vitamins (Henderson's medium)	–
Hildebrandt's medium + yeast extract (5 g./l.)	+
Heller's medium	–
Heller's medium + yeast extract (5 g./l.)	+
Gautheret's medium (containing coconut milk, casein hydrolysate)	–
Gautheret's medium + IAA (10^{-5}, 10^{-4}, and 10^{-3} g./l.)	–
Gautheret's medium + NAA (10^{-5}, 10^{-4}, and 10^{-3} g./l.)	–
Gautheret's medium + 2,4-D (10^{-5}, 10^{-4}, and 10^{-3} g./l.)	–
Gautheret's medium + yeast extract (2 g./l.) (No coconut milk)	++
Nitsch's medium	–
Nitsch's medium + tomato juice (20% by volume)	+
Nitsch's medium + yeast extract (5 g./l.)	++++

Growth response was recorded 3 weeks after orignal explantation; – = No cell division, ± = Little cell division, + = Apparent but limited proliferation, ++–++++ = Active proliferation; Test tissue: Midseason yellow sugary (32 × 33), late season yellow sugary (72 × 73), waxy Hy × L317, and starchy Hy × L317.

were tested, with and without supplements, for their ability to support the growth of excised endosperm. The test materials were all single cross hybrids: a midseason yellow sugary (32 × 33), a late season yellow sugary (72 × 73), Golden Cross Bantam (P51 × P39)[4], a waxy (Hy × L317), and

[4] The authors are grateful to Mr. Glenn M. Smith for the supply of sugary inbred lines and hybrids.

a starchy (Hy × L317). These plants were self-pollinated in the greenhouse, and, 7 to 15 days later, the young ears were harvested and explants of endosperm were made as indicated above.

No growth of explants was observed on any of the basal media tested (Table 1). The addition singly of various materials, such as IAA, NAA, 2,4-D, coconut milk, casein hydrolysate, adenine, and vitamins, did not result in growth response of explants. However, appreciable growth of the tissue took place where Difco yeast extract had been added to the basal media (2 to 5 g./l.). With White's, Hildebrandt's, Heller's, and Gautheret's media the induced growth was limited and subculturing was unsuccessful, and the addition of larger amounts of yeast extract (5 g./l.) was inhibitory. With Nitsch's medium supplemented with yeast extract at 5 g./l., on the other hand, the proliferation was vigorous and the first transfer of new tissue was successful with all types of test tissue including starchy and waxy endosperm. The ability of subcultures to grow through subsequent transfers varied with the type of endosperm as follows: (a) Subcultures of Golden Cross Bantam (P51 × P39) and midseason yellow sugary (32 × 33) grew only for 5 to 6 weeks and died; (b) subcultures of waxy (Hy × L317) and starchy (Hy × L317) grew well at first, then gradually lost vigor, and finally ceased growing about 5 months after original excision; (c) subcultures of late season yellow sugary (72 × 73) have shown continuous growth for 8 months through 15 transfers.

When tomato juice was substituted for yeast extract, the growth response of explants was erratic. Waxy endosperm did not grow on this medium. The addition of IAA to the yeast extract medium at concentrations of 10^{-5}, 10^{-4}, and 10^{-3} g./l. was somewhat inhibitory to the initial growth of explants.

Based on the results mentioned above Nitsch's medium supplemented with Difco yeast extract (5 g./l.) was used as the basic medium in the following experiments.

Growth response of excised endosperm from different inbred lines and single crosses. Straus and LaRue (1954) reported that of 15 varieties tested, only 2 sugary open-pollinated varieties, "Surprise Sweet" and "Black Mexican", could be depended upon to give uniform results, and that none of the several waxy or starchy varieties tested showed any growth response. In the preceding experiment, waxy and starchy corn endosperm tissue were also grown for a considerable period of time. In an experiment to determine the adaptability of various types of endosperm to cultivation in vitro, 25 different inbred lines and certain selected single crosses among them were used. Plants were field-grown and hand-pollinated. Explants were made 9 to 13 days after pollination and in some instances this range was expanded from 5 to 30 days. Nitsch's medium supplemented with yeast extract (5 g./l.) was used.

TABLE 2. *Growth response of excised endosperm from different inbred lines and single crosses.*

	Good growth	Poor response	No response
Inbred lines	Yellow Sugary su_2su_2[b]	Evergreen (#7)	Waxy Hy
	Black Mexicane	Evergreen (#8)	Starchy Hy
	Starchy L317[c]	Country Gentleman (#5)	P51
	Waxy L317[c]	Country Gentleman (#6)	Starchy 38-11
		Waxy Wf9	Floury (#22)
		Starchy Wf9	South American
		Waxy 38-11	Jap Hulless
		P39	Supergold
		HA	Tr
		Floury (#20)	
		Floury (#21)	
		Brittle	
Hybrids	Late Season Yellow Sugary (72 × 73)[a]	Floury (21 × 20)	Evergreen (7 × 8)
		Starchy Wf9 × Starchy Wf9	Evergreen (8 × 7)
	Country Gentleman (5 × 6)[b]	Starchy 38-11 × Starchy L317	Waxy Hy × Waxy Wf9
	Country Gentleman (6 × 5)[b]	Flint (17 × 18)	Waxy Wf9 × Waxy Hy
	Starchy L317 × Starchy 38-11[c]		
		P39 × P51	Waxy Hy × Starchy Hy
	Waxy L317 × Starchy L317[c]	P51 × P39	Starchy Hy × Waxy Hy
	Starchy L317 × Waxy L317[c]		Waxy Wf9 × Starchy Wf9
	Waxy Hy × Waxy L317[c]		Starchy Wf9 × Waxy Wf9
	Starchy Hy × Starchy L317[c]		Waxy 38-11 × Starchy 38-11
			Floury (22 × 21)
			South American × Jap Hulless
			South American × Supergold
			P51 × Tr
			Tr × P51

[a] Growing vigorously for 8 months after original explant. [b] Growing vigorously for 4 months after original explant. [c] Grew for 2 to 5 months after orignal explant, then died. Medium: Nitsch's medium supplemented with 5 g./l. Difco yeast extract.

The results are summarized in Table 2. Excised endosperm classified under "good growth" includes explants that showed active proliferation. The newly formed tissue was successfully transferred to new media and kept alive for at least 2 months. One-half of the isolates in this group are still growing at the present time (1/30/58), encompassing a period of over 4 months and 5 to 8 successful transfers (fig. 1 A–E). The second group,

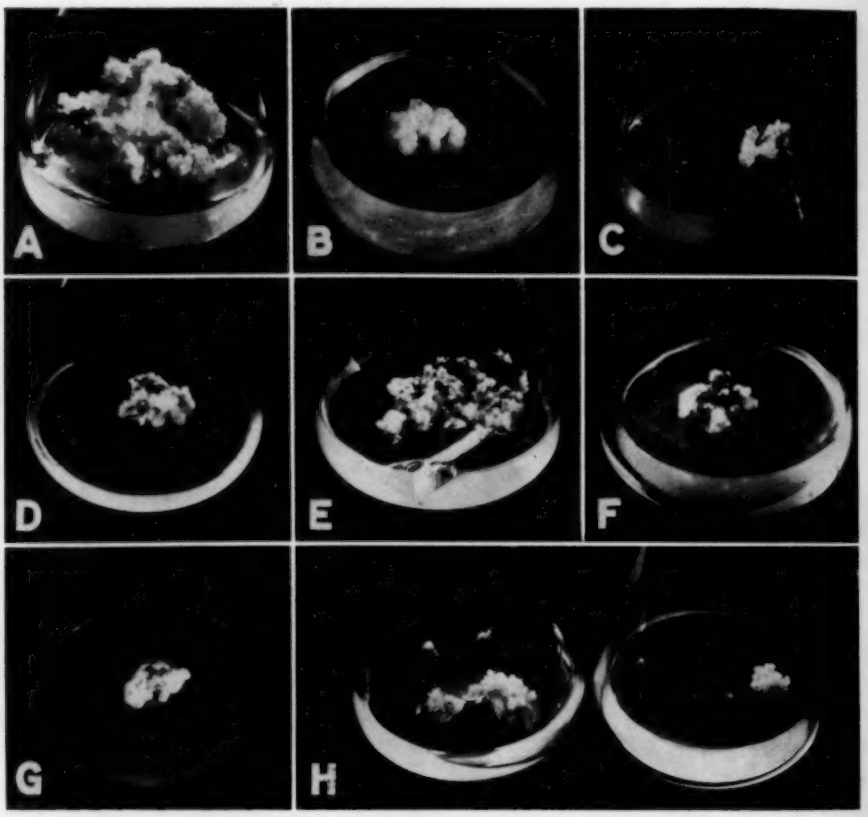

FIG. 1. Excised corn endosperm grown *in vitro* on Nitsch's medium supplemented with 5 g./l. Difco yeast extract. A. Late season yellow sugary hybrid (72 × 73). 35 days old. Friable type. B. Late season yellow sugary hybrid (72 × 73). 20 days old. Solid type. C. Yellow sugary of genotype of su_2su_2. 30 days old. D. Country Gentleman hybrid (5 × 6). 30 days old. E. The reciprocal cross of D (6 × 5). 35 days old. F. Starchy L317 × starchy 38-11 hybrid. 30 days old. G. Starchy L317 × waxy L317 hybrid. 24 days old. Note smooth surface characteristics of slow growing culture. Growth ceased (in the 3rd transfer) 45 days later. H. Late season yellow sugary hybrid (72 × 73) after 21-day incubation. Inital weight approximately 2 mg., size of initial explants shown by the 3 pieces that failed to grow in the flask on the right.

under "poor response", includes cultures in which the original explants showed some cell division, but the first transfer was not successful. The

two endosperm types, brittle and floury, proliferated as vigorously as those in the first group. It is possible that these two types may be successfully subcultured. The third group, under "no response", includes endosperm in which the explants showed no detectable cell division.

Table 3 shows the relation of growth response to age of endosperm as

TABLE 3. *Growth response of excised corn endosperm in relation to age as calculated from the time of pollination until excision.*

	Inbred Lines						Hybrids		
Days after pollination	Black Mexican	Waxy L317	Starchy L317	Floury (#20)	Yellow Sugary su_2su_2	Brittle	Waxy L317 × Starchy L317	Starchy L317 × Starchy 38-11	Starchy L317 × Waxy L317
6						+			
7	++		±		+	++			
8	++	+	±	±	±	++	±		+
9	++	+	±	+	±	±	±	+	+
10	+	±	+	+	+	−	±	±	+
11	±	±	+	±	±	−	±	±	±
12	−	±	±	−	−	−	−	−	−
13	−	−	−	−	−	−	−	−	−
14	−	−	−	−	−	−	−	−	−
15	−	−	−	−	−	−	−	−	−
20	−	−	−	−	−	−	−	−	−
30	−	−	−	−	−	−	−	−	−

Growth response was recorded 3 weeks after original explantation; − = No cell division, ± = Little cell division, + = Apparent but limited proliferation, ++ = Active proliferation; Medium: Nitsch's medium supplemented with 5 g./l. Difco yeast extract.

calculated from the time of pollination until excision. It is apparent that only young endosperm grew in vitro. Endosperm isolated 12 days after pollination failed to grow. Excision of tissue from kernels less than 6 days after pollination was exceedingly difficult because of their small size. Thus, 8 to 11 days post-pollination seems to be the best period to obtain explants for the cultivation of corn endosperm in vitro.

Effect of growth factors. It was pointed out in the section in which basal media were compared that the growth induction of original explants was not promoted by the addition singly of IAA, NAA, or 2,4-D to the media. In this experiment further tests of growth factors were made using endosperm tissue that had been well established in culture.

The test tissue primarily used was that of late season yellow sugary (72×73). In some instances, however, other hybrids and an inbred line were also tested including Country Gentleman (5×6), its reciprocal (6×5), and a yellow sugary of the genotype of su_2su_2. They gave similar results to those obtained with late season yellow sugary (72×73). The initial weight of the test tissue was 10 to 20 mg. Total growth was determined after 3 weeks incubation by removing each piece from the flask and weighing it.

Yeast extract appears to be essential for the growth of excised endosperm of corn, with an optimum concentration of about 5 g. per liter (fig. 2). The growth of tissue on filtered yeast extract was slightly better than that on autoclaved yeast extract.

The growth-promoting effect of coconut milk has been shown for various plant tissue cultures (Steward & Shantz 1956). Such an effect was not observed with endosperm of corn. When coconut milk, either filtered or autoclaved, was substituted for yeast extract poor growth of tissue resulted.

The addition of casein hydrolysate (vitamin-free) to the yeast extract medium (1 g./l.) did not increase growth of the test tissue beyond that of the medium without it.

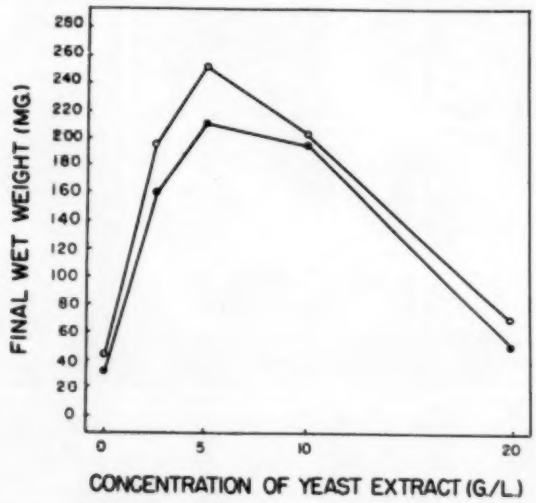

FIG. 2. Effect of yeast extract on the growth of corn endosperm tissue *in vitro*. Medium: Nitsch's medium supplemented with different concentrations of Difco yeast extract; Test tissue: Late season yellow sugary (72 × 73), Country Gentleman (6 × 5); Initial weight: 10–20 mg.; Incubation period: 3 weeks.

The effect of IAA was tested at three different concentrations: 10^{-5}, 10^{-4}, and 10^{-3} g./l. The growth of tissue was not affected appreciably except at the highest concentration where a slight inhibition appeared (fig. 3).

No effect was noted on the growth of established endosperm tissue cultures by the addition of NAA (5×10^{-4} g./l.). However, with young tissue (about one month from the time of excision), some retardation and eventual death occurred after the second or third transfer on the same medium. The effect of 2,4-D (5×10^{-4} g./l.) was practically the same as that of NAA mentioned above.

No stimulatory effect of gibberellic acid was observed at 10^{-2} g. per liter, nor was there any remarkable inhibition of growth. As in the case of

gibberellic acid, neither significant stimulatory nor inhibitory effect was observed with kinetin at a concentration of 10^{-4} g. per liter.

Size of seed piece in relation to growth. To examine the effect of the relative size of seed-pieces to subsequent growth, portions of tissue weighing 2 to 30 mg. were removed from tissue cultures of late season yellow sugary (72 × 73) and of Country Gentleman (6 × 5), and placed on the medium. Over 90 percent of the seed-pieces weighing 10 mg. or more grew. Among seed-pieces weighing less than 10 mg., successful establishment appeared to be proportional to weight. Thus of those weighing about 2 mg. only 40 percent survived transfer (fig. 1 H).

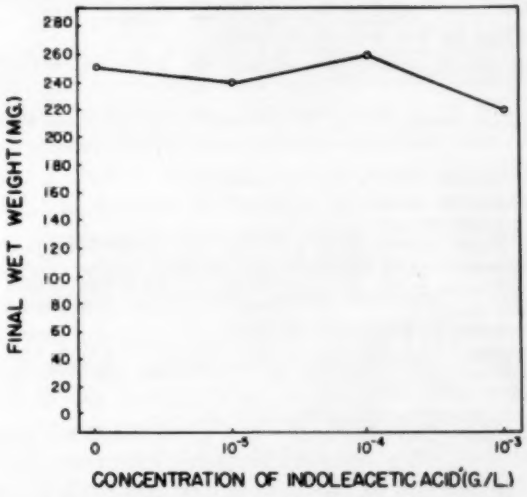

FIG. 3. Effect of indoleacetic acid on the growth of corn endosperm tissue *in vitro*. Medium: Nitsch's medium supplemented with 5 g./l. Difco yeast extract; Test tissue: Late season yellow sugary (72 × 73); Incubation period: 3 weeks.

Growth ability in relation to growth type of tissue. It was observed that endosperm tissue sometimes grew as a solid mass, and sometimes as a friable mass (fig. 1 A, B). In the latter, the tissue consisted of clumps of cells that were easily separable from one another. This tendency to fragment seemed to correlate closely with active growth. It is to be noted in this connection that cultures that died after 2 to 5 months, (waxy, starchy, and their hybrid endosperm) invariably changed their growth behavior from the friable type into the solid type as they lost vigor (fig. 1 G).

Attempts to cultivate excised meristem tissue of corn. Different sizes of explants were removed from meristem tissue of young corn plants and tested for their ability to grow in vitro. Among various media tested (Table 4), Gautheret's medium was the only one that induced proliferation of meristem explants. New cells apparently originated in the inter-

calary meristem just above the node. These new cells were sometimes small, hyaline and distributed irregularly over the meristem layer; they did not develop further, but seemed to remain alive for a long period of time as judged by appearance. Sometimes, however, active proliferation occurred, and the whole tissue took a crown-like shape. These cells were active for only a few days and then began to turn brown. In both cases, subculturing of new tissue was unsuccessful.

With explants, which consisted of either nodal or internodal tissue, no cell division was observed. When the explant was relatively large and contained more than two nodes, it tended to show normal growth which resembled the growth of a small, excised shoot. No appreciable growth of tissue was observed in the liquid culture.

The addition of supplements shown in Table 4, either singly or in

TABLE 4. *Culture media tested for cultivation of meristem tissue of corn.*

White's medium
White's medium + alcohol extract of corn smut gall
White's medium + alcohol extract of germinating corn embryo
White's medium + yeast extract (1 g./l.)
White's medium + yeast extract (1 g./l.) + IAA (10^{-5}, and 10^{-4} g./l.)
White's medium + tomato juice (20% by volume)
White's medium + tomato juice (20% by volume) + IAA (10^{-5}, and 10^{-4} g./l.)
Hildebrandt's medium
Hildebrandt's medium + IAA (2×10^{-3} g./l.)
Hildebrandt's medium + IAA (2×10^{-3} g./l.) + kinetin (2×10^{-6}, and 2×10^{-5} g./l.)
Hildebrandt's medium + IAA (2×10^{-3} g./l.) + kinetin (2×10^{-5} g./l.) + yeast extracts (5 g./l.)
Hildebrandt's medium + gibberellic acid (10^{-2} g./l.)
Hildebrandt's medium + gibberellic acid (10^{-2} g./l.) + kinetin (2×10^{-6}, and 2×10^{-5} g./l.)
Hildebrandt's medium + yeast extract (5 g./l.)
Hildebrandt's medium + coconut milk (18% by volume)
Hildebrandt's medium + adenine + vitamins (Henderson's medium)
Heller's medium
Heller's medium + yeast extract (2 g./l.)
Gautheret's medium
Gautheret's medium + coconut milk (18% by volume)
Gautheret's medium + yeast extract (2 g./l.)
Gautheret's medium + yeast extract (2 g./l.) + NAA (10^{-5}, 10^{-4}, and 10^{-3} g./l.)
Gautheret's medium + yeast extract (2 g./l.) + 2,4-D (10^{-5}, 10^{-4}, and 10^{-3} g./l.)
Nitsch's medium
Nitsch's medium + yeast extract (1, 5, and 10 g./l.)
Nitsch's medium + yeast extract (5 g./l.) + IAA (10^{-5}, 10^{-4}, and 10^{-3} g./l.)
Nitsch's medium + yeast extract (1 g./l.) + tomato juice (20% by volume)

combination, did not induce growth of excised meristem tissue, but generally accelerated the browning of the cut surface of the tissue in contact with the substrate.

Gibberellic acid was an exception in that it did not promote browning of explants. Moreover, the gibberellic acid medium occasionally induced growth of tissue. In one case, where a relatively long explant containing two nodes was used (about 8 mm.), a remarkable elongation of the inter-

nodes occurred which ultimately attained about 8 cm. in total length. This elongation, a characteristic effect of gibberellic acid, was distinct from the undifferentiated growth of small explants observed with Gautheret's medium.

Yeast extract, when added to Gautheret's medium at the concentration of 2 g. per liter, appeared to support better and more uniform growth induction of explants than the control medium. A similar effect was also obtained with coconut milk (18% by volume). At a higher concentration (5 g./l.), yeast extract accelerated discoloration of tissue.

The growth response differed considerably among inbred lines and single crosses on Gautheret's medium.

Discussion. The growth response of excised corn endosperm varied greatly among inbred lines and their crosses. Some showed no cell division, some did poorly, and some very well. The successful first transfer of newly formed tissue to new media was obtained with 4 of 25 inbreds and with 8 of 32 single crosses. These four inbreds included two of sugary, one of waxy, and one of starchy endosperm. The eight hybrids included three of sugary, one of waxy, two of starchy, and two of waxy × starchy endosperm. In the succeeding transfers, however, the nonsugary cultures gradually lost their vigor and finally died in 2 to 5 months (fig. 1 F, G). On the other hand, all sugary endosperm cultures except one have shown continuous growth without evident decrease in growth rate. The reason why waxy and starchy endosperm tissue ceased growing after 2 to 5 months growth is not known. One of the possibilities may be a lack of factor(s) in the medium essential to the growth of these particular tissues. If the factor(s) concerned were known, it might not only promote unlimited growth of these tissues but also lead to information on physiological differences among waxy, starchy, and sugary endosperm. Even though limited in time, these seem to be the first instances of growth of waxy and of starchy endosperm tissue in vitro.

It seems highly probable that the tissue cultures of sugary endosperm (yellow sugary of the genotype of su_2su_2, late season yellow sugary (72 × 73), Country Gentleman (5 × 6), and its reciprocal (6 × 5)) will grow indefinitely. Supporting evidence for this view is supplied by the initial survival of 40 percent of the seed-pieces weighing about 2 mg. This is surprising when the relative amount of damage to the cells is taken into consideration. This, together with the fact that the tissue that developed from each of those 2 mg. of seed-pieces is still growing through several transfers, may indicate that their growth is due to the capacity of the tissue to utilize the nutrients in the medium rather than to the carry-over of materials from the mother tissue.

Two types of growth, friable and solid, were observed in endosperm tissue cultures. Similar phenomena were also reported with other types

of tissues (Gautheret 1956; Henderson 1954; Muir, Hildebrandt & Riker 1954; Reinert 1956; Torrey and Shigemura 1957; Tryon 1955). Torrey and Shigemura (1957) reported that the growth type of pea root callus tissue was determined by the relative concentrations of yeast extract and 2,4-D in the medium and that high yeast concentrations relative to the 2,4-D concentration favored the conversion of the solid type to the friable type, which is evidently an irreversible process. With respect to corn endosperm tissue these two types of growth were apparently reversible on the same media. The friable type was usually accompanied by active growth, and the solid type by slow growth.

The loss of ability of excised endosperm to grow in vitro when collected 12 days after pollination suggests that the physiological conditions of the developing endosperm had changed at that stage.

Straus and LaRue (1954) reported that the tissue they used could grow on a medium without yeast extract but supplied with casein hydrolysate or a less complex mixture of 5 amino acids. Growth of tissue was only about one-third of that attained on the yeast extract medium. The present experiment showed that the further addition of casein hydrolysate to the yeast extract medium had no effect on the growth of tissue. Since it is apparent that yeast extract contained a beneficial factor(s) other than amino acids, further work is necessary to determine the basis for its essentiality in corn endosperm tissue culture. It is to be noted that Difco yeast extract was much superior to another brand in growth-promoting action.

Torrey and Shigemura (1957) found that 2,4-D had a marked synergistic effect in the presence of yeast extract on the growth of pea root callus tissue. NAA was also reported by them to stimulate callus development in the presence of yeast extract although IAA was inactive. Established tissue cultures of corn endosperm on the yeast extract medium did not respond to the growth substances tested (IAA, NAA, 2,4-D, kinetin, and gibberellic acid). This does not mean, however, that those factors are not required by the tissue. Stowe, Thimann & Kefford (1956) found that LaRue's isolate (CE Clone 1-C) contained a large quantity of IAA, which amounted to approximately 1 mg./kg. This was one hundred times that found in the total medium on which the tissue had grown, and consequently, excluded a speculation that the tissue concentrated IAA from the medium. The negative response of corn endosperm to the growth substances tested may provide evidence supporting the conclusion of Stowe, Thimann & Kefford that the tissue is capable of self-production of auxin. It is to be added in this regard that IAA and other growth substances have been reported to be either ineffective or inhibitory to the growth of crown gall tumor tissues, which are believed to synthesize auxins. (Braun 1954, de Ropp 1947, Klein 1957.)

With respect to the cultivation of meristem tissue of corn Gautheret's medium supplemented with either coconut milk (18% by volume) or yeast extract (2 g./l.) was most favorable. The failure of Nitsch's medium, which is the best medium for endosperm tissue culture, to induce any growth response of meristem tissue suggests that the nutritional requirements of these two types of tissue may be different. It appears that testing of various modifications of Gautheret's medium with emphasis on the vitamin and minor element components might yield a favorable response.

The size and nature of the explant are important factors to be considered in meristem tissue culture. The only part from which new cells developed seemed to be the intercalary meristem, a layer of tissue just above each node. This is the region in which cell division occurs in the culm. As long as this tissue was included explants were able to show a growth response.

SUMMARY

1. A modified Nitsch's medium was found to be satisfactory for the cultivation of excised endosperm tissue of corn. This medium consists of a simplified Knop solution, minor elements, sucrose, thiamine, pyridoxine, cysteine, and Difco yeast extract.

2. Endosperm tissue excised 8 to 11 days after pollination produced the optimum growth. There was a marked decrease in the ability of explants to grow after this stage. The successful first transfer of newly formed tissue was made with 4 inbreds (two of sugary, one of waxy, and one of starchy endosperm) and with 8 single crosses (three of sugary, one of waxy, two of starchy, and two of waxy × starchy endosperm). Among these isolates, four from sugary endosperm (one inbred and three hybrids) have shown continuous growth for over 4 months through more than 5 transfers. All of them have high growth rates, and some have survived for as long as 8 months and appear to be able to grow indefinitely. Subcultures of waxy and starchy endosperm tissue, on the other hand, showed only limited growth (2–5 months).

3. The established cultures on the yeast extract medium did not respond to indoleacetic acid or other growth substances (NAA, 2,4-D, kinetin, and gibberellic acid) or to casein hydrolysate at the concentrations used. Coconut milk was unable to replace yeast extract.

4. Actively growing cultures were usually very friable, whereas slowly growing tissue tended to be solid.

5. For the cultivation of excised meristem tissue of corn, Gautheret's medium, supplemented with either coconut milk (18% by volume) or yeast extract (2 g./l.), was found to be promising. Small explants having intercalary meristem tissue developed new cells on this medium, although subculturing of new tissue was unsuccessful. Nodal or internodal tissue

showed no cell division. All growth substances tested were ineffective under the conditions employed.

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BULLETIN OF THE TORREY BOTANICAL CLUB

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TORREYA

FIELD TRIP REPORTS

March 30. St. John's in the Wilderness. A Joint Torrey-Rockland Audubon group attended this service (see Torreya in Bull. Torrey Club **81**: 460, 1954, **82**: 397, 1955, **83**: 385, 1956, and **84**: 318, 1957). Two unseasonably late, heavy snowfalls left the trails with two feet of snow, and the group, 'sans' snowshoes, were forced to remain on the highway. Botanizing was limited to the observance of woody plants in heavy bud. Attendance: Torrey 9, Rockland-Audubon 3. Leader J. Harry Lehr.

BOOK REVIEWS

Principles of Plant Pathology. By E. C. Stakman and J. George Harrar. xi + 581 pages. The Ronald Press Company, 15 East 26th Street, New York 10, New York. 1957. $8.00.

This new book deals chiefly and admirably with plant pathological principles and concepts. It is well written and well illustrated, easy to read and interesting, scientific but not highly technical. The stress on the future needs in the light of past and present accomplishments in plant pathology is a salient feature of the text. It should prove invaluable to the more serious student of plant pathology.

After a brief introduction, Chapter 1 discusses the importance of plants and the complete dependence of mankind on the plant kingdom. Chapters 2, 3 and 4 follow with a general discussion on the economic importance of plant diseases, definitions and concepts of disease, symptom expression and bases for disease classification. Animate and inanimate causes of plant diseases are discussed. A brief but excellent key on nutritional deficiencies is given. Chapters 5 through 10 deal with plant pathogens, their general characteristics, various ecologic and symbiotic relations among them, growth and reproduction, the genetic complexities of species—including genetic and phenotypic variability, adaptation, mutation and hybridization —, the various kinds of inoculum, its production, liberation and longevity, local and distant dissemination and the phenomenon of infection including a brief discussion on the physiology of spore germination, penetration and establishment. The effect of environment and nutrition on disease development is the subject of Chapter 11. While the reader is constantly reminded, throughout the book that plant diseases are international problems, Chapter 12 deals with internationally important plant diseases. Disease controls through quarantines and eradication campaigns, cultural practices, chemicals and immunization are outlined in Chapters 14 through 17. Chapter 13, on diseases in transit and storage is set apart as a reminder that "the responsibilities of the plant pathologist do not end with the harvest of satisfactory yields of plant products. Harvesting marks the termination of one phase of plant pathology, . . . the second phase is the protection of seeds, fruit, vegetables and other economic plant parts from the time of harvest until they reach the consumer." The final chapter (18) reviews the past progress, discusses present problems and future prospects of plant pathology.

Selected references are cited at the end of each chapter and one of the 3 appendices gives an excellent list of important books in plant pathology. The other appendices list the Latin binomials of the principal pathogens and insects cited in the text. Conveniently there is both an author and subject index.—RAYMOND CAPPELLINI, Department of Plant Pathology, Rutgers, the State University of New Jersey, New Brunswick, New Jersey.

Soil-Plant Relationships. By C. A. Black. John Wiley & Sons, Inc., New York, N. Y. 1957. 332 pp. Illustrated.

The book makes an integrated analysis of soil-plant relationships, drawing on both soil technology and plant physiology. The author states in the introduction that the

subject matter in the book is covered by his own course in soils at Iowa State College. The level of presentation is intended to be suitable for advanced undergraduate students who have already attained considerable knowledge of soils, plant physiology and the basic sciences. Each of the nine chapters represents a kind of unit with separate literature citations. The skeleton chapter headings are, Soil Composition; Soil Water; Soil Aeration; Exchangeable Bases; Soil Acidity; Soil Salinity and Alkalinity; Nitrogen; Phosphorus; and Potassium; together with eight pages of index. The content can be illustrated with topics from Chapter 8 on Phosphorus, as follows: Content in Soils; Losses from Soils; Forms in Soils; Availability to Plants; Function in Plants; and Phosphorus Supply and Plant Behavior. Chapter 9 on Potassium involves the amount in the soil, crop removal, leaching, availability to plants, its fixation in soil, function in plants, deficiency symptoms, potassium deficiency and susceptibility to disease, potassium deficiency and low temperature injury.

There are practical touches throughout the book and plenty of literature citations for the ambitious students. The reviewer has the impression that this book would supply the basis of a substantial course in advanced soils. Plant physiologists and others interested in growing plants will find this a valuable book.—P. W. ZIMMERMAN, Boyce Thompson Institute for Plant Research, Inc., Yonkers 3, N. Y.

The Experimental Control of Plant Growth. By Frits W. Went. Chronica Botanica Co., Waltham, Mass., 1957. 343 pp. Illustrated, $8.50.

The book is divided into three parts: I. Construction and Operation of the Earhart Plant Research Laboratory; II. Climatic Response of Individual Plants; and III. General Discussion. There are 26 chapters of text, bibliography, author index, subject index, and 25 glossy plates in the back of the book.

There are detailed descriptions of construction and operation of the Clark Greenhouses and the Earhart Laboratories. The purpose was to provide facilities where plants could be grown under controlled environmental conditions. Such factors as moisture, temperature, and light could be completely regulated. Relative sterility in the growing rooms was maintained by filtration of air, sterilization of material going into the laboratory, and selection of plant material which was free from disease. Plants were moved from place to place on wheeled trucks of different sizes to meet requirements. Growing methods were standardized with reference to root medium, watering, nutrient solutions, water softeners, and containers in order to bring about reliability of environmental control.

In the author's own words (p. ix), "Since this book is mainly a record of the operation of and the results obtained in the Clark Greenhouses and the Earhart Plant Research Laboratory, very little related work by others is included, and hardly any pertinent literature references are quoted, since this would have extended the book beyond reasonable limits." As is, it includes experimental data accumulated through 1956, with a few references to results in 1957.

The book has a personal touch as evidenced by such phrases as "It is my conviction that", "It is my belief that," etc.

While the chapters of the book contain experimental results, they are not shaped as manuscripts which are published in scientific journals. Part I takes care of methods and materials. Part II handles results with individual plants, referred to by the author as "autecology." Part III deals with "general physiological problems, and with ecology and climatology as far as plants are concerned." The book as a whole is a record of experimental work in air-conditioned greenhouses and laboratories.

Five chapters of the book were written by other experts in particular fields. Chapter 8, by Lloyd Evans, deals with temperature effects in relation to photo period. Chapter 11, by Wm. M. Hiesey, covers genetics and physiology of grasses. Chapter 14, by Henry Hellmers, concerns the ecology of "chaparral plants" in the San Gabriel mountains. Chapter 23, by W. C. Ashby, reports results of various methods for determining water loss by plants. Chapter 25, "Biochemistry," by Arthur W. Galston, deals with "auxins"

and "adenine." The author recognized the importance of controlled temperature while determining the exact effects of auxins on plants. He made the following significant statements (p. 313): "Despite more than twenty-five years of intensive research on auxins, we still have no clear concept of whether any intact plants are limited in their normal growth because of a deficiency in auxin. . . . We know of no experiments, however, which have clearly demonstrated an enhancing effect of auxin upon the normal vegetative growth of any plant."

The designation "phytotron" was first given to the Earhart Laboratory. It was meant to imply a comprehensive set of air-conditioned greenhouses and rooms for plants similar to a large cyclotron or synchrotron.

This book is a record of experimental work in a new air-conditioned set of greenhouses,and laboratories. It is interesting to read, and will no doubt be used by botanists and research laboratories all over the world.—P. W. ZIMMERMAN, Boyce Thompson Institute for Plant Research, Inc., Yonkers 3, New York.

Quantitative Plant Ecology. By P. Greig-Smith. 198 pages. Academic Press, Inc., Publishers, London.

Some ecologists have attempted in recent years to place their science on a more objective basis. They realized that conclusions drawn from subjective sampling were open to considerable error and therefore might be invalid. Those wishing a more exact science have developed methods of objective sampling and have also turned to statistical analysis as a further tool for obtaining objectiveness.

QUANTITATIVE PLANT ECOLOGY is one of the first attempts to bring together various available statistical methods that can be applied to ecological data which will aid in placing ecology on a more exact mathematical basis. In approaching the subject of quantitative ecology it remains to be seen whether the complex total environment-plant relationship is subject to an accurate mathematical expression. Nevertheless, before this relationship can be seen and understood, its parts must be comprehensible. Statistical analyses have aided in interpreting parts of the total relationship and theoretically may be employed to interpret the whole.

Mr. Greig-Smith elected to discuss quantitative ecology in seven categories: (1) Quantitative Description of Vegetation, (2) Sampling and Comparison, (3) Pattern, (4) Association Between Species, (5) Correlation of Vegetation with Habitat Factors, (6) Plant Communities, and (7) The Quantitative Approach to Plant Ecology. His discussion of quantitative description of vegetation deals primarily with different quantitative methods in use and the validity of information given by each. The difficulty of comparing two areas by popular methods is considered. An illustration is employed to demonstrate how such comparisons can be made. The first portion of Chapter 2 deals with disadvantages of drawing conclusions from quadrat data without first submitting them to statistical analysis. Later in the chapter he attempts to show how conclusions can be made if positioning and number of quadrats are adequate. Eight methods of detecting randomness or nonrandomness are treated in Chapter 3. Chi-square and correlation coefficient are used to illustrate association between species. These tests are capable of showing both positive and negative association. They do not necessarily demonstrate a causal relationship between species involved nor do they show a common reaction to any one environmental factor. These tests just show the presence of the association. After this has been satisfactorily demonstrated, the causative agent must be sought to explain the association. In Chapter 4, the chi-square contingency table, t-test, analysis of variance, and regression analysis are touched upon very slightly in an attempt to demonstrate how they might be used in handling certain types of data. The suggested methods are excellent for determining correlation between environmental factors and vegetation. The subject of delimiting plant communities on an objective basis is treated in Chapter 6. Various methods that have been used are reviewed in an attempt to point out the type of information that can be obtained from each. Chapter 7 gives Mr. Greig-Smith's philosophy concerning the possible contribution of statistics to ecologi-

cal theory. Within the appendices, correlation of meteorological data with ecological phenomena and area and spread of species are briefly presented.

Mr. Greig-Smith has presented many available statistical methods that can be used in ecological work. He has in no way attempted to present all that are applicable. The book is heavy on chi-square and as a consequence there is a tendency for the author only to suggest other methods that also have merit in ecological investigation.

The value of this book lies not in the thoroughness of subject coverage but in the review of a rapidly developing phase of ecology. The statistician will probably find the book elementary. The investigator with no statistical background will find the book difficult, for the author did not present detailed examples, however, references are made to places where details can be obtained. Also, his conclusions are given largely in statistical terminology. This is a criticism of most investigators employing statistics for data analysis. Too often researchers write in statistics rather than English. This makes it exceedingly difficult for non-statisticians to grasp the full significance of reported results. The book, QUANTITATIVE PLANT ECOLOGY, will probably profit those investigators who have a slight working knowledge of statistics, for heretofore unseen applications are presented.—CARL D. MONK, Department of Botany, Rutgers University, New Brunswick, N. J.

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ABBREVIATIONS OF TITLES OF SERIALS CITED BY BOTANISTS[1]

LAZELLA SCHWARTEN AND HAROLD WILLIAM RICKETT

Eleven years ago we published a list of the abbreviations used at that time in the "Index to American Botanical Literature." This Index has appeared in the BULLETIN OF THE TORREY BOTANICAL CLUB for some seventy-three years, and is received as a card index by several libraries; part of it is reprinted as "The Taxonomic Index," published in BRITTONIA. The conventions of citation that appear in the Index are therefore familiar to a wide botanical public. Moreover they are based on the old rules for citation adopted at the Madison Botanical Congress of 1893, which also served as a model for the "Guide to the citation of botanical literature" that forms Appendix V of the *International Code of Botanical Nomenclature* (1956). These conventions, therefore, while not explicitly sanctioned by any botanical organization, may claim a certain international standing.

In the time that has elapsed since 1947, many additional serials have been examined in the compilation of the "Index." It was our first intention to issue, from time to time, supplements to the original list of abbreviations; for various reasons this intention was never realized. A supplement would now be larger than the list, and it is better to issue an entirely new list which includes the titles of the old one with the later additions.

The purpose of the original list was stated in a brief introduction. It was made, first, as a convenience for the compilers of the Index; then, at the suggestion of several friends, it was published, as a guide for those who might want to achieve in this way consistency of citation. That there are many who found it useful is evident from the urging we have had to continue it. If a list of abbreviations of serials is indeed useful, then it should not be limited to those which happen to have been used in the "Index." Accordingly in the present compilation we have included others frequently cited by botanists, regardless of country of origin and currency. Not only is it useful to have standard abbreviations; the information here provided on the exact titles and the provenance of the serials is often valuable to persons who have no access to a large botanical library.

A complete list of all serials in which botanists write may perhaps be thought desirable. Such a list is obviously beyond the capacity of two individuals; it would require an organization established for the purpose. Moreover the actual usefulness of what could be achieved is debatable. It

[1] Reprints of this list are available from the authors, who regret that they feel compelled to make a charge of 35¢ a single copy, or $3.00 for 10.

would soon be out of date. It would include many titles very rarely cited by botanists. And it could not resolve the problem of the limits of botany. The present work sets forth not only a *list of abbreviations,* but also a *method of abbreviating.* Any botanist who will use the method can easily abbreviate titles as he finds it necessary to cite them; and such abbreviations will be to some extent self-explanatory. This is particularly important to the plant physiologist, whose interests lead him to cite chemical and other serials besides those that can properly be called botanical. On the other hand, taxonomists are more plagued by the necessity for correct citation than botanists of other specialities, and the selection of titles listed below includes, for this reason, many of the more obscure publications in which taxonomic work has appeared. It is also rather heavily weighted in favor of cis-atlantic titles, partly because of its development from the "Index." We shall welcome suggestions for the inclusion of additional titles in a possible supplement or new edition. And we shall be glad to have errors of citation pointed out; they are almost inevitable in a compilation of this kind.

In abbreviating titles we have aimed at consistency. Our first principle has been to retain the order of words that actually appears on the cover or title-page of the publication: Trans. Am. Philos. Soc. for *Transactions of the American Philosophical Society,* but Brit. Mycol. Soc. Trans. for *The British Mycological Society. Transactions.* If covers and title-page differ, as they sometimes do, then the title-page is taken as the more authoritative (being the more permanent). The method has one obvious disadvantage: the different publications of one institution may become alphabetically separated. Ann. Missouri Bot. Gard. is thus divorced from Missouri Bot. Gard. Bull. But this inconvenience is small compared with the nuisance of hunting in indexes and bibliographies for such a title first under "Missouri," then under "Bull." and finally perhaps locating it under "St. Louis." Few serials have more than one title; but any method of listing them other than by title offers alternatives for particular serials.

In general each word of the title is abbreviated to its first syllable; one or more letters of the second syllable may be retained, for various reasons. "Bulletin" becomes Bull., "Journal" Jour., "Annals" Ann. Perhaps there is no more reason for two l's in Bull. than for the addition of an n to Jour.; here we follow custom. In other titles the use of additional letters avoids confusion: Philip. Jour. Sci.; Proc. Acad. Phila.; Trans. Am. Philos. Soc. Titles of one word are not abbreviated: Brittonia, Phytopathology. Names of persons also are written in full: Bull. Torrey Club; Jour. Elisha Mitchell Soc.

Articles, conjunctions, and other small words are generally omitted. Words have been added to the titles of some serials to distinguish them from the similar or identical titles of serials of different origin: Not. Syst.

Leningrad and Not. Syst. Paris; Natura Buenos Aires and Natura S. Paulo. Formerly such additions were placed in brackets. There seems now no sufficient reason for doing so. The abbreviation as a whole is a symbol, its purpose to enable the reader to find something. It is of little use to show what elements of the abbreviation have been added by the person who made it—and it is a nuisance.

In listing the titles in full we have also indicated the provenance (institution, society, city, etc.) of each. This is explicit in some titles, as in *Boletín de la Sociedad Argentina de Botánica; Occasional Papers of the Bernice Pauahi Bishop Museum;* or in subtitles, as in *Acta Botanica Neerlandica. Official Publication of the Koninklijke Nederlandse Botanische Vereniging.* To others the requisite information is added in brackets, before or after the title as it may appear in the publication itself: *Svensk Botanisk Tidskrift.* [Svenska Botaniska Föreningen.]. Such information may appear on the covers or title-page but cannot be interpreted as properly a part of the title. When the title has varied, the alternative words are shown in parenthesis; the most recent title is the one abbreviated. (Occasionally a parenthesis is a part of the title or subtitle itself, and does not correspond with information inserted by us.) If the serial has appeared in several series, only the most recent is shown (by a Roman numeral): Ann. Sci. Nat. Bot. XII. Earlier series may be indicated in the same way.

Other lists of abbreviations have been published. The United States Department of Agriculture has its own, to which all its employees are expected to adhere. *Biological Abstracts* has a similar system. There is also a *World list of scientific periodicals published in the years 1900–1950.* Why should we add another? Why should we not adjust our citations to one of these standards? One answer is that every one likes his own way. Such a preference, though frivolously expressed, may have a rational basis. It is true that the very existence of something called a "World list" suggests its adoption as an international standard. It seems, however, not to have been sponsored by an international organization, and it was apparently compiled by British librarians. And there are, in our opinion, objections to the acceptance of the abbreviations therein proposed. The comments that follow deal explicitly with the *World list;* they may also apply to several of the other systems that have been proposed.

The editors of *World list* must be congratulated on the completion of a task so enormous. But the very size of the result defeats the purposes of its users, whose interests very rarely extend to all science. Size also multiplies errors and inconsistencies. Many titles now current are lacking from the *World list,* many have changed their names. Some titles are wrongly stated: "Bulletin. American Orchid Society"; "Yearbook. American Philosophical Society." Even if one accepts the canons of abbreviation set forth in the introduction, they seem not to have been consistently

followed in the list itself. Some abbreviations are unnecessarily long; some words, in fact, are not abbreviated at all; while others are abbreviated or contracted almost to extinction. If Exp. will do for "Experimental," "Expedition" being shortened to Exped., then surely Agr. will do for "Agriculture" and its cognates, Agron. being reserved for "Agronomy." Phil., on the other hand, is not good enough for "Philosophical," in view of the several other words that begin with this syllable. Am. is enough for "American"; another syllable adds nothing useful. Cienc. and Cient. contrast strangely with Sci.; Ci. would do. J. for "Journal" might also mean Jahrbuch, Jahresbericht, Jaarboek, Jaaresverslag; and why not A. for "Annals," B. for "Bulletin"? And I can think of no excuse for Gdn and Sth for "Garden" and "Southern." Some words inserted in the abbreviations are unnecessary, as Atti Ist. Bot. *Univ.* Pavia, for there is no botanical institute in Pavia other than that of the University; and Ann. *Bot.* Herb. Santa Catarina, for an herbarium issues only botanical works.

The question of the necessity of this word or that in a proposed abbreviation needs scrutiny. In an article written for botanists and published in a serial devoted entirely to botany, Bull. Torrey Club is surely sufficient for *Bulletin of the Torrey Botanical Club*. There are no other Torrey Clubs with which this could be confused. But in other contexts, the insertion of Bot. may be advisable. Similar remarks apply to publications of academies of science. Few readers of a scientific article in a scientific serial are likely to be misled by Proc. Calif. Acad. into calling for the proceedings of an academy of letters or fine arts. The point is that a list of abbreviations need not and should not be absolute. Once the principles that it exemplifies are accepted, the formulae may be varied to suit the occasion. If some of our abbreviations seem too brief for some purposes, they may be easily enlarged: Bull. Torrey Bot. Club; Bol. Acad. Ci. Fís. Mat. Nat. Caracas; Proc. Am. Acad. Arts Sci.; Trans. Acad. Sci. St. Louis; Jour. Elisha Mitchell Sci. Soc. Or if any are unnecessarily detailed, the remedy is obvious.

ABBREVIATIONS OF CERTAIN WORDS COMMONLY FOUND IN TITLES

Academia, Académie, Academy: Acad.
Agricultura, Agricultural, Agriculture: Agr.
Agronomía, Agronomy: Agron.
Akademie, Akademiia: Akad.
Alabama: Ala.
American: Am.
Anales: Anal.
Annales, Annals: Ann.
Archiv, Archives, Archivos: Arch.
Arizona: Ariz.
Arkansas: Ark.
Arkiv: Ark.
Arquivos: Arq.

Beihefte: Beih.
Berichte: Ber.
Bibliographia, Bibliography: Bibliogr.
Bibliot(h)eca: Bibliot.
Biological, Biology: Biol.
Boletim, Boletín: Bol.
Bolletino: Boll.
Botánica, Botanical, Botanik, Botanique, Botanische, Botany: Bot.
Bryological, Bryology: Bryol.
Bulletin: Bull.
California: Calif.
Ciencia(s), Ciência(s), Científico: Ci.
Collectanea, Collections: Collect.
College: Coll.
Colorado: Colo.
Comunicaciones: Com.
Connecticut: Conn.
Contributions: Contr.
Department: Dep.
Ecological, Ecology: Ecol.
Expedition: Exped.
Experimental: Exp.
Flora: Fl.
Florida: Fla.
Foundation: Found.
France, Français: Fr.
Garden: Gard.
Georgia: Ga.
Genetica, Genetics: Genet.
Gesellschaft: Ges.
Giornale: Gior.
Handlingar: Handl.
Herbarium: Herb.
Heredity: Hered.
Historia, Historical, History: Hist.
Horticultural, Horticulture, Hortus: Hort.*
Idaho: Ida.
Illinois: Ill.§
Institut, Institute, Instituto: Inst.
Jahrbuch, Jahrbücher: Jahrb.
Jahresbericht: Jahresb.
Jardin, Jardín: Jard.
Journal: Jour.
Kansas: Kan.
Kentucky: Ky.
Leaflet(s): Leafl.
Louisiana: La.
Magasin, Magazine: Mag.
Maine: Me.
Maryland: Md.
Massachusetts: Mass.
Meddelelser: Meddel.
Mededeelingen: Meded.

* But "Horti" is not abbreviated; to replace one letter by a period is not worth while.

§ "Indiana" and "Indian" should not be abbreviated, for obvious reasons.

Mémoires: Mém.
Memoirs, Memorias: Mem.
Michigan: Mich.
Minnesota: Minn.
Mississippi: Miss.*
Miscellanea, Miscellaneous: Misc.
Mitt(h)eilungen: Mitt.
Monographs: Monogr.
Montana: Mont.
Museo, Museu, Museum, Muséum: Mus.
Mycological, Mycologique, Mycology: Mycol.
Nacional: Nac.
National: Natl.§
Natura, Natural, Naturalist, Nature, Naturel: Nat.
Naturforschende: Naturf.
Naturhistorische: Naturh.
Naturvidenskapene: Naturv.
Naturwissenschaftliche: Naturw.
Natuurkundig: Natuurk.
Natuurwetenschappelijk: Natuurw.
Nebraska: Nebr.
Nevada: Nev.
New Hampshire: N. H.
New Jersey: N. J.
New Mexico: N. M.
New York: N. Y.
North Carolina: N. C.
North Dakota: N. D.
Notiser, Notulae: Not.
Occasional: Occ.
Oklahoma: Okla.
Oregon: Ore.
Pacific: Pacif.
Papers: Pap.
Pennsylvania: Pa.
Philadelphia: Phila.
Philippine: Philip.
Philosophic(al): Philos.
Physiology: Physiol.
Plant: Pl.
Proceedings: Proc.
Publication(s): Publ.
Quarterly: Quart.
Report: Rep.
Research: Res.
Review: Rev.
Royal: Roy.
Science(s), Scientific: Sci.
Skrifter: Skr.
Sociedad, Società, Societas, Société, Society: Soc.
Special: Spec.

* "Missouri" should not be abbreviated. "Mo." is incomprehensible to those unfamiliar with it and "Miss." (as any resident of the state knows) is often used even by Americans for "Missouri."

§ In general we do not approve of contractions (as distinct from abbreviations); but this one seems needed.

South: S.
South Carolina: S. C.
South Dakota: S. D.
Southern: So.
State: St.
Station: Sta.
Svenska: Sv.
Tennessee: Tenn.
Texas: Tex.
Tidskrift: Tidskr.
Transactions: Trans.
Universidad, Universidade, Université, University: Univ.
Vere(e)niging, Verein: Ver.
Verhandelingen, Verhandlungen: Verh.
Vermont: Vt.
Videnskaberne, Videnskapelige: Vid.
Virginia: Va.
Washington: Wash.
West Virginia: W. Va.
Wisconsin: Wis.
Wissenschaftliche: Wiss.
Wyoming: Wyo.
Zeitschrift: Zeitschr.
Zeitung: Zeit.

TITLES OF SERIALS

A.A.A.S. Proc.—American Association for the Advancement of Science. Summarized Proceedings. [Title varies; formerly "Proceedings of the American Association for the Advancement of Science."]

Acadian Nat.—Acadian Naturalist. Bulletin of the Natural History Society of New Brunswick. [Canada.]

Acta Agron.—Acta Agronómica. [Facultad de Agronomía—Palmira. Universidad Nacional de Colombia.]

Acta Bot. Fenn.—Acta Botanica Fennica. [Societas pro Fauna et Flora Fennica.]

Acta Bot. Neerl.—Acta Botanica Neerlandica. Official publication of the Koninklijke Nederlandse Botanische Vereniging (Royal Botanical Society of the Netherlands). [Continuation of "Nederlandsch Kruidkundig Archief" and "Recueil des Travaux Botaniques Néerlandais."]

Acta Ci. Potos.—Acta Científica Potosina. [Universidad Autónoma de San Luis Potosí.]

Acta Horti Berg.—Acta Horti Bergiani. Meddelanden från Kungl. Svenska Vetenskapsakademiens Trädgård. [Bergielund.]

Acta Horti Gothob.—Acta Horti Gothoburgensis. Meddelanden från Göteborgs Botaniska Trädgård.

Acta Phytogeogr. Suec.—Acta Phytogeographica Suecica. [Svenska Växtgeografiska Sälskapet.]

Acta Soc. Bot. Polon.—Acta Societatis Botanicorum Poloniae. Organ Polskiego Towarzystwa Botanicznego. Publication de la Société Botanique de Pologne.

Acta Soc. Fauna Fl. Fenn.—Acta Societatis pro Fauna et Flora Fennica.

Addisonia—Addisonia. Colored illustrations and popular descriptions of plants. [The New York Botanical Garden.]

Agr. Hist.—Agricultural History. [The Agricultural History Society.]

Agr. Téc.—Agricultura Técnica. [Santiago de Chile.]

Agr. Trop.—Agricultura Tropical. Organo de la Asociación Colombiana de Ingenieros Agrónomos.

Agron. Jour.—Agronomy Journal. [Continuation of "Journal of the American Society of Agronomy."]

Agron. Lusit.—Agronomia Lusitana. [Estação Agronómica Nacional, Sacavém.]
Agron. Trop.—Agronomía Tropical. Revista del Centro de Investigaciones Agronómicas. [Maracay.]
Akad. Nauk SSSR Mém. VII.—[See Mém. Acad. St.-Pétersb. VIII.]
Akad. Wien. Sitz-ber.—Akademie der Wissenschaften in Wien. Mathematisch-naturwissenschaftliche Klasse. Sitzungsberichte. Abt. I. [Title has varied. Earlier volumes as "Sitzungsberichte der mathematisch-naturwissenschaftlichen Classe der (kaiserlichen) Akademie der Wissenschaften (in Wien). (Abteilung I.)"]
Aliso—(El) Aliso. A series of papers on the native plants of California. [Rancho Santa Ana Botanic Garden, Claremont, California.]
Allan Hancock Atl. Exped. Rep.—Allan Hancock Atlantic Expedition. Report. [The University of Southern California Press.]
Allan Hancock Found. Publ.—Allan Hancock Foundation Publications. (Occasional Paper.)
Allan Hancock Pacif. Exped.—(The) (Allan) Hancock Pacific Expeditions. [The University of Southern California Press.]
Am. Bot.—The American Botanist. A quarterly journal of economic and ecological botany. [Indianapolis.]
Am. Fern Jour.—American Fern Journal. [The American Fern Society.]
Am. Forests—American Forests. [The American Forestry Association.]
Am. Jour. Bot.—American Journal of Botany. [The Botanical Society of America.]
Am. Jour. Sci.—American Journal of Science. [Yale University.]
Am. Midl. Nat.—The American Midland Naturalist. [Notre Dame University.]
Am. Nat.—The American Naturalist. [The American Society of Naturalists.]
Am. Orchid Soc. Bull.—American Orchid Society Bulletin.
Am. Philos. Soc. Yearb.—The American Philosophical Society held at Philadelphia for promoting useful knowledge. Year Book.
Anais Acad. Brasil.—Anais da Academia Brasileira de Ciências. [Vols. 1–12 (1929–1940) as Annaes da Academia Brasileira de Sciencias.]
Anais Herb. Barbosa Rodrigues—Anais Botânicos do Herbário "Barbosa Rodrigues."
Anal. Acad. Chil.—[Revista Universitaria.] Anales de la Academia Chilena de Ciencias Naturales. [Universidad Católica de Chile.]
Anal. Esc. Ci. Biol. Mexico—Anales de la Escuela Nacional de Ciencias Biológicas. [Mexico.]
Anal. Inst. Biol. México—Anales del Instituto de Biología de la Universidad Nacional de México.
Anal. Inst. Bot. Cavanilles—[Consejo Superior de Investigaciones Científicas.] Anales del Instituto Botánico A. J. Cavanilles (Anales del Jardín Botánico de Madrid). [Also as "Instituto Botánico Antonio José Cavanilles."]
Anal. Jard. Bot. Madrid—[See Anal. Inst. Bot. Cavanilles.]
Anal. Mus. Argent. Ci. Nat.—Anales del Museo Argentino de Ciencias Naturales "Bernardino Rivadavia." [Buenos Aires.]
Anal. Mus. Patag.—Anales del Museo de la Patagonia. [Continued as Mus. Nahuel Huapí Anal.]
Anal. Soc. Ci. Argent.—Anales de la Sociedad Científica Argentina.
Anal Univ. S. Domingo—[See Univ. S. Domingo Anal.]
Ann. ACFAS—Annales de l'ACFAS [Association Canadienne-Française pour l'Avancement des Sciences].
Ann. Appl. Biol.—The Annals of Applied Biology. [Association of Applied Biologists. England.]
Ann. Bogor.—Annales Bogorienses. A journal of tropical general botany being a continuation of the Annals of the Botanic Garden, Buitenzorg.
Ann. Bot. II.—Annals of Botany. New Series. [Oxford, England.]
Ann. Bot. Gard. Buitenzorg—['s Lands Plantentuin (Botanic Gardens, Buitenzorg, Java).] Annals of the Botanic Gardens, Buitenzorg. Being a continuation of the Annales du Jardin Botanique de Buitenzorg.

Ann. Cryptog. Phytopath.—Annales Cryptogamici et Phytopathologici (incorporating Annales Bryologici). [Waltham, Massachusetts.]

Ann. Éc. Agr. Montpellier—Annales de l'École Nationale d'Agriculture de Montpellier.

Ann. Jard. Bot. Buitenzorg—Annales du Jardin Botanique de Buitenzorg. [Continued (1941) as Ann. Bot. Gard. Buitenzorg.]

Ann. Missouri Bot. Gard.—Annals of the Missouri Botanical Garden.

Ann. Mus. Col. Marseille—Annales du Musée Coloniale de Marseille.

Ann. N. Y. Acad.—Annals of the New York Academy of Sciences.

Ann. Naturh. Mus. Wien—Annalen des Naturhistorischen Museums in Wien. [Formerly "Annalen des K. K. Naturhistorischen Hofmuseums."]

Ann. Sci. Nat. Bot. XII.—Annales des Sciences Naturelles. 12e série. Botanique et biologie végétale. [Paris.]

Appalachia—Appalachia. [The Appalachian Mountain Club.]

Arb. Bull.—Arboretum Bulletin. [University of Washington, Seattle.]

Arch. Inst. Biol. Veg. Rio de Janeiro—Archivos do Instituto de Biologia Vegetal. [Rio de Janeiro. See Inst. Biol. Def. Agr. Rio de Janeiro Bol. and Arch. Jard. Bot. Rio de Janeiro. Superseded by Arq. Serv. Flor. Rio de Janeiro.]

Arch. Inst. Bot. Liège—Archives de l'Institut (de) Botanique de l'Université de Liège.

Arch. Jard. Bot. Rio de Janeiro—Archivos do Jardim Botânico do Rio de Janeiro. [Superseded in 1933 (with Inst. Biol. Def. Agr. Rio de Janeiro Bol.) by Arch. Inst. Biol. Veg. Rio de Janeiro. Reinstated (1947) as Arq. Jard. Bot. Rio de Janeiro.]

Ark. Bot. II.—Arkiv för Botanik. Andra serien. [Kungl. Svenska Vetenskapsakademien.]

Arq. Bot. S. Paulo II.—Arquivos de Botânica do Estado de São Paulo. Nova serie formato maior.

Arq. Inst. Biol. S. Paulo—Arquivos do Instituto Biológico. [Departamento da Defesa Sanitária da Agricultura. São Paulo.]

Arq. Jard. Bot. Rio de Janeiro—[Ministério da Agricultura.] Arquivos do Jardim Botânico do Rio de Janeiro. [An earlier series, Arch. Jard. Bot. Rio de Janeiro (vols. 1–6, 1915–1933) was superseded by Arq. Serv. Flor. The above series was reinstated in 1947 with vol. 7.]

Arq. Mus. Rio de Janeiro—Arquivos do Museu Nacional. [Rio de Janeiro.]

Arq. Mus. Paran.—[Universidade do Paraná. Museu Paranaense (Secretaria de Educação e Cultura do Estado do Paraná).] Arquivos do Museu Paranaense.

Arq. Serv. Flor. Rio de Janeiro—Arquivos do Serviço Florestal. [Ministéria da Agricultura. Rio de Janeiro. See Arch. Inst. Biol. Veg. Rio de Janeiro.]

Asa Gray Bull.—The Asa Gray Bulletin. New Series. [The Gray Memorial Botanical Association, Botanical Gardens Association of the University of Michigan, and the Michigan Botanical Club.]

Assoc. Am. Geogr. Ann.—Association of American Geographers. Annals.

Atoll Res. Bull.—Atoll Research Bulletin. [Pacific Science Board, National Academy of Sciences—National Research Council.]

Atti Ist. Bot. Pavia—Atti dell'Istituto Botanico "Giovanni Briosi" e Laboratorio Crittogamico Italiano della R. Università di Pavia.

Atti Reale Accad. Napoli II.—[Società Reale de Napoli.] Atti della Reale Accademia delle Scienze Fisiche e Matematiche. Serie seconda.

Austral. Jour. Bot.—Australian Journal of Botany. [Commonwealth Scientific and Industrial Research Organization and the Australian National Research Council.]

Baileya—Baileya. A quarterly journal of horticultural taxonomy. [Bailey Hortorium, Cornell University.]

Bartonia—Bartonia. Journal of the Philadelphia Botanical Club.

Beih. Bot. Centr.—Beihefte zum Botanischen Centralblatt.

Belmontia I.—Belmontia. Miscellaneous publications in botany. I. Taxonomy. [Laboratory of plant taxonomy and geography, Agricultural University, Wagen-

ingen. Reprints from other serials. Other series are: II. Ecology; III. Horticulture; IV. Incidental.]

Ber. Deutsch. Bot. Ges.—Berichte der Deutschen Botanischen Gesellschaft.

Ber. Schweiz. Bot. Ges.—Berichte der Schweizerischen Botanischen Gesellschaft. [Also as "Bulletin de la Société Botanique Suisse."]

Bibliogr. Genet.—Bibliographia Genetica. [Supplement to Genetica. See also Resum. Genet. 's-Gravenhage.]

Bibliot. Argent. Ci. Nat.—[Instituto Nacional de Investigación de las Ciencias Naturales, Buenos Aires.] Biblioteca Argentina de Ciencias Naturales. [Museo Argentino de Ciencias Naturales "Bernardino Rivadavia."]

Bibliot. Bot.—Bibliotheca Botanica. Original-Abhandlungen aus dem Gesamtgebiete der Botanik. [Stuttgart.]

Biol. Bull. Woods Hole—The Biological Bulletin. [The Marine Biological Laboratory, Woods Hole.]

Biol. Leafl.—Biological Leaflet. [Leon Kelso.]

Biol. Rev.—Biological Reviews of the Cambridge [England] Philosophical Society.

Biologist—The Biologist. [The Phi Sigma Society.]

Biota—Biota. [Instituto Salesiano "Pablo Albera," Magdalena del Mar, Perú.]

Bishop Mus. Bull.—Bernice P. Bishop Museum Bulletin.

Bishop Mus. Spec. Publ.—Bernice P. Bishop Museum Special Publication.

Blumea—Blumea. Tijdschrift voor de Systematiek en de Geografie der Planten (a Journal of Plant Taxonomy and Plant-Geography). [Rijksherbarium, Leiden.]

Boissiera—Boissiera. Mémoires du Conservatoire de Botanique et de l'Institut de Botanique Systématique de l'Université de Genève. [Supplement of "Candollea."]

Bol. Acad. Caracas—[Estados Unidos de Venezuela.] Boletin de la Academia de Ciencias Fisicas, Matemáticas y Naturales. [Caracas.]

Bol. Fitossan.—Boletim Fitossanitário. [Divisão de Defesa Sanitária Vegetal. Ministerio da Agricultura. Brazil.]

Bol. Inst. Bot. Quito—Boletín del Instituto Botánico de la Universidad Central. [Quito.]

Bol. Mus. Hist. Nat. Lima—Boletín del Museo de Historia Natural "Javier Prado." [Lima.]

Bol. Mus. Rio de Janeiro—Boletim do Museu Nacional. [Rio de Janeiro.]

Bol. Soc. Argent. Bot.—Boletín de la Sociedad Argentina de Botánica.

Bol. Soc. Bot. Méx.—Boletín de la Sociedad Botánica de México. [Continuation of Soc. Bot. Méx. Bol.]

Bol. Soc. Brot.—Boletim da Sociedade Broteriana. [Instituto Botânico da Universidade de Coimbra.]

Bol. Soc. Geogr. Lima—Boletín de la Sociedad Geográfica de Lima.

Bol. Soc. Venez. Ci. Nat.—Boletín de la Sociedad Venezolana de Ciencias Naturales.

Bol. Téc. Caracas—[Ministerio de Agricultura y Cria.] Boletín Técnico. [Caracas.]

Bol. Téc. Genét. Fitotéc. Chile—Boletín Técnico. [Ministero de Agricultura. Departamento de Genética Fitotécnica. Santiago de Chile.]

Bol. Téc. Inst. Agron. Belém—Boletim Técnico do Instituto Agronômico do Norte. [Belém.]

Bol. Téc. Inst. Cacau Bahia—Boletim Técnico. Instituto de Cacau da Bahia.

Bot. Arch.—Botanisches Archiv. [Leipzig.]

Bot. Bull. Acad. Sin.—Botanical Bulletin of Academia Sinica. A quarterly journal containing scientific contributions from the Institute of Botany, Academia Sinica. [Shanghai.]

Bot. Gaz.—The Botanical Gazette. [The University of Chicago.]

Bot. Jaarb.—Botanisch Jaarboek. [Natuurwetenschappelijk Genootschap Dodonaea, Gent. Superseded by "Biologisch Jaarboek."]

Bot. Jahrb.—Botanische Jahrbücher für Systematik, Pflanzengeschichte und Pflanzengeographie. [Leipzig.]

Bot. Leafl. Sherff—Botanical Leaflets (published by the author). [Earl Edward Sherff.]

Bot. Mag.—Curtis's Botanical Magazine containing coloured figures with descrip-

tions and observations on the botany history and culture of choice plants. New series. [The Royal Horticultural Society.]

Bot. Mag. Tokyo—The Botanical Magazine, Tokyo. [The Botanical Society of Japan.]

Bot. Mus. Leafl.—Botanical Museum Leaflets. [Harvard University.]

Bot. Not.—Botaniska Notiser. [Lunds Botaniska Förening.]

Bot. Not. Suppl.—Botaniska Notiser. Supplement. [Lunds Botaniska Förening. Continued as Op. Bot.]

Bot. Rev.—The Botanical Review, interpreting botanical progress. [The New York Botanical Garden.]

Bot. Tidsskr.—Botanisk Tidsskrift. [Dansk Botanisk Forening.]

Bot. Zeit.—Botanische Zeitung. [Leipzig.]

Bot. Zhur.—Botanicheskii Zhurnal (Organ Vsesoĭuznovo Botanicheskovo Obshchestva). [Izdatelstvo Akademii Nauk SSSR.]

Bothalia—Bothalia. A record of contributions from the National Herbarium, Union of South Africa. [Pretoria.]

Bragantia—Bragantia. Boletim Técnico do Instituto Agronômico do Estado de São Paulo.

Brit. Col. Prov. Mus. Rep.—[Province of British Columbia. Department of Education.] Provincial Museum of Natural History and Anthropology. Report.

Brit. Mycol. Soc. Trans.—The British Mycological Society. Transactions.

Brittonia—Brittonia. Publication of The American Society of Plant Taxonomists. [The New York Botanical Garden.]

Bryologist—The Bryologist. Journal of the Sullivant Moss Society.

Bull. Am. Rock. Gard. Soc.—Bulletin of the American Rock Garden Society. [Including "Saxiflora."]

Bull. Biogéogr. Montréal—Bulletin du Service de Biogéographie. [Service de Biogéographie, Université de Montréal.]

Bull. Bot. Gard. Buitenzorg III.—['s Lands Plantentuin (Botanic Gardens, Buitenzorg, Java).] Bulletin of the Botanic Gardens, Buitenzorg. Being a continuation of the Bulletin du Jardin Botanique de Buitenzorg. Série III. [Continued as Reinwardtia.]

Bull. Brit. Mus. Bot.—Bulletin of the British Museum (Natural History). Botany.

Bull. Chicago Acad.—Bulletin of the Chicago Academy of Sciences.

Bull. Herb. Boiss. II.—Bulletin de l'Herbier Boissier. 2me série.

Bull. Inst. Jamaica Sci.—Bulletin of the Institute of Jamaica. Science Series.

Bull. Jard. Bot. Bruxelles—Bulletin du Jardin Botanique de l'État. [Bruxelles.]

Bull. Jard. Bot. Montréal—Bulletin du Jardin Botanique de Montréal. [Title sometimes in English; see Bull. Montreal Bot. Gard.]

Bull. Linn. Soc. Lyon—Bulletin Mensuel de la Société Linnéenne de Lyon. [Formerly "Bulletin Bi-mensuel."]

Bull. Montreal Bot. Gard.—Bulletin of the Montreal Botanic Garden. [Title sometimes in French; see Bull. Jard. Bot. Montréal.]

Bull. Mosk. Obshch. Isp. Pri. Biol.—Biŭlleten Moskovkovo Obshchestva Ispitatelei Prirodi. Otdel Biologicheskii. Novaia seriia. Bulletin de la Société (Impériale) des Naturalistes de Moscou. Section biologique. Nouvelle série. [Title formerly in French only.]

Bull. Mus. Hist. Nat. Paris II.—Bulletin du Muséum National d'Histoire Naturelle. 2e série. [Paris.]

Bull. Scripps Inst. Oceanogr.—Bulletin of the Scripps Institution of Oceanography (of the University of California). Technical Series. [La Jolla.]

Bull. So. Calif. Acad.—Bulletin of the Southern California Academy of Sciences.

Bull. Soc. Bot. Belg.—Bulletin de la Société Royale de Botanique de Belgique.

Bull. Soc. Bot. Fr.—Bulletin de la Société Botanique de France.

Bull. Soc. Bot. Genève—Bulletin de la Société Botanique de Genève.

Bull. Soc. Bot. Suisse—Bulletin de la Société Botanique Suisse. [See Ber. Schweiz. Bot. Ges.]

Bull. Soc. Hist. Nat. Toulouse—Bulletin de la Société d'Histoire Naturelle de Toulouse.
Bull. Soc. Nat. Moscou—[See Bull. Mosk. Obshch. Isp. Pri. Biol.]
Bull. Torrey Club—Bulletin of the Torrey Botanical Club (and Torreya).
Butler Univ. Bot. Stud.—Butler University Botanical Studies.

Cact. Sucul. Mex.—Cactáceas y Suculentas Mexicanas. Organo de la Sociedad Mexicana de Cactología, A. C.
Cact. Succ. Jour.—Cactus and Succulent Journal of the Cactus and Succulent Society of America (, Inc).
Caldasia—Caldasia. Boletín del Instituto de Ciencias Naturales de la Universidad Nacional de Colombia—Bogotá.
Canad. Field-Nat.—The Canadian Field-Naturalist. Ottawa Field-Naturalists' Club.
Canad. Jour. Bot.—Canadian Journal of Botany. [National Research Council of Canada. Continuation of "Canadian Journal of Research. Section C. Botanical Sciences."]
Canad. Jour. Res. C.—Canadian Journal of Research. Section C. Botanical Sciences. [Continued as "Canadian Journal of Botany."]
Candollea—Candollea. Organe du Conservatoire et du Jardin Botaniques de la Ville de Genève.
Carib. Forest.—The Caribbean Forester. [U. S. Department of Agriculture Forest Service. Tropical Forest Research Center. Río Piedras, Puerto Rico.]
Carnegie Inst. Publ.—Carnegie Institution of Washington [D. C.]. Publication.
Carnegie Inst. Yearb.—Carnegie Institution of Washington [D. C.]. Year Book.
Castanea—Castanea. The Journal of the Southern Appalachian Botanical Club.
Ceiba—Ceiba, a scientific journal issued by the Escuela Agrícola Panamericana. [Tegucigalpa.]
Cellule—La Cellule. Recueil de cytologie et d'histologie. [Louvain.]
Ceres—Revista Ceres. Publicação de ensinamentos teóricos e práticos sôbre agricultura, veterinária, indústrias rurais. [Universidade Rural do Estado de Minas Gerais.]
Česká Mykol.—Česká Mykologie. Casopis Cs. vědecké spolecnosti pro mykologii pro sířeni znalosti hub po stránce vědecké i praktické. [Československá Vědecká Společnost pro Mykologii.]
Ceylon Jour. Sci. A.—Ceylon Journal of Science. Section A. Botany. [University of Ceylon, Colombo.]
Chron. Bot.—Chronica Botanica, an international collection of studies in the method and history of biology and agriculture. [Waltham, Massachusetts.*]
Chron. Nat.—Chronica Naturae. [Koninklijke Natuurkundige Vereeniging (in Nederlandsch-Indie).] Official organ of the Organization for Scientific Research in Indonesia. [Continuation of Natuurw. Tijd. Ned. Ind. Continued as Madj. Ilmu Alam Indon.]
Circ. U. S. Dep. Agr.—Circular. United States Department of Agriculture.
Collect. Bot. Barcelona—[Ayuntamiento de Barcelona. Consejo Superior de Investigaciones Científicas. Instituto Municipal de Ciencias Naturales.] Collectanea Botanica a Barcinonensi Botanico Instituto edita.
Com. Bot. Mus. Hist. Nat. Montevideo—Comunicaciones Botánicas del Museo de Historia Natural de Montevideo.
Com. Inst. Invest. Ci. Nat. Buenos Aires Bot.—[Ministero de Educación de la Nación. Dirección General de Cultura.] Comunicaciones del Instituto Nacional de Investigación de las Ciencias Naturales. Museo Argentino de Ciencias Naturales "Bernardino Rivadavia." Ciencias Botánicas.
Com. Inst. Trop. Invest. Ci. Salvador—Comunicaciones. Instituto Tropical de Investigaciones Científicas. [Universidad de El Salvador.]
Compt. Rend. Acad. Paris—Comptes Rendus hebdomadaires des Séances de l'Académie des Sciences. [Paris.]
Compt. Rend. Acad. URSS.—Comptes Rendus (Doklady) de l'Académie des Sciences

* Issued from Waltham in the past; future place of publication unknown to us.

de l'URSS. Nouvelle série. Doklady Akademii Nauk SSSR. Novaĭa Seriĭa. [After 1946 title in Russian only: see Dokl. Akad. SSSR.]

Compt. Rend. Lab. Carlsb. Physiol.—Comptes Rendus des Travaux du Laboratoire de Carlsberg. Édition française. Série physiologique.

Contr. Arct. Inst. Cathol. Univ.—Contribution of the Arctic Institute—The Catholic University of America.

Contr. Bot. Lab. Univ. Pa.—Contributions from the Botanical Laboratory (and the Morris Arboretum) of the University of Pennsylvania. [Later volumes are reprints.]

Contr. Boyce Thompson Inst.—Contributions from Boyce Thompson Institute.

Contr. Dudley Herb.—Contributions from the Dudley Herbarium (of Stanford University).

Contr. Fl. Nev.—Contributions toward a Flora of Nevada. [National Arboretum and New Crops Research Branch, U. S. Department of Agriculture.]

Contr. Fl. Wyo. Leafl.—Contributions toward a Flora of Wyoming. Leaflet. [The Rocky Mountain Herbarium, University of Wyoming.]

Contr. Gray Herb.—Contributions of the Gray Herbarium of Harvard University.

Contr. Herb. Univ. W. Va.—Contributions from the Herbarium of the University of West Virginia.

Contr. Inst. Biol. Univ. Montréal—Contributions de l'Institut de Biologie. [Title varies: until 1940, "Contributions de l'Institut de Zoologie de l'Université de Montréal"; for a brief period "Contributions de l'Institut de Biologie Générale et de Zoologie (de l'Université de Montréal.)"]

Contr. Inst. Bot. Univ. Montréal—Contributions de l'Institut Botanique de l'Université de Montréal.

Contr. Inst. Oka—Contributions de l'Institut d'Oka (Université de Montréal).

Contr. Ocas. Mus. Hist. Nat. Col. "De La Salle"—Contribuciones Ocasionales del Museo de Historia Natural del Colegio "De La Salle." [Havana.]

Contr. Tex. Res. Found. Bot.—Contributions from the Texas Research Foundation. Botanical Studies. [Renner.]

Contr. U. S. Nat. Herb.—Contributions from the United States National Herbarium. [United States National Museum, Smithsonian Institution.]

Contr. Univ. Mich. Herb.—Contributions from the University of Michigan Herbarium.

Cranbrook Inst. Bull.—Cranbrook Institute of Science. Bulletin. [Bloomfield Hills, Michigan.

Curr. Sci. Bangalore—Current Science. [Bangalore.]

Cytologia—Cytologia. International Journal of Cytology. Internationale Zeitschrift für Zytologie. Archives Internationales de Cytologie. [Tokyo.]

Dansk Bot. Ark.—Dansk Botanisk Arkive (Res Botanicae Danicae). [Dansk Botanisk Forening.]

Danske Vid. Selsk. Biol. Meddel.—Kgl. Danske Videnskabernes Selskab. Biologiske Meddelelser.

Darwiniana—[Ministerio de Educación de la Nación. Dirección General de Cultura. Academia Nacional de Ciencias Exactas, Físicas y Naturales de Buenos Aires.] Darwiniana. Revista del Instituto de Botánica Darwinion.

Des. Pl. Life—Desert Plant Life. [American Succulent Societies.]

Dokl. Akad. SSSR—Dokladi Akademii Nauk SSSR. Novaĭa Seriĭa. [Continuation of Compt. Rend. Acad. URSS.]

Duke Univ. Forest. Bull.—Duke University School of Forestry. Bulletin.

Ecol. Monogr.—Ecological Monographs. [The Ecological Society of America.]

Ecology—Ecology. [The Ecological Society of America. Formerly "Plant World."]

Econ. Bot.—Economic Botany. Devoted to applied botany and plant utilization. [The New York Botanical Garden.]

Erythea—Erythea. A journal of botany, west American and general. [University of California.]

Farlowia—Farlowia. A journal of cryptogamic botany. [Farlow Library and Herbarium of Harvard University.]
Fauna Fl. Uppsala—Fauna och Flora. Populär Tidskrift för Biologi. [Uppsala & Stockholm.]
Field Lab.—Field and Laboratory. Contributions from the Science Departments of Southern Methodist University.
Fieldiana Bot.—Fieldiana: Botany. [Continuation of "Publications of Field Museum of Natural History. Botanical Series." The Chicago Natural History Museum.]
Fl. Males. Bull.—Flora Malesiana Bulletin. [The Hague.]
Fla. Geol. Surv. Rep.—Florida Geological Survey. Annual Report.
Flora—Flora oder Allgemeine Botanische Zeitung. [Jena.]
Flora Quito—Flora. Revista de Botánica y Farmacognosía. Organo oficial del Instituto Botánico de la Universidad Central. [Quito.]
Fl. Fauna Kjøbenhavn—Flora og Fauna. [Naturhistorisk Forening for Jylland med Stotte af Underviningsministeriet.]
Forest Sci.—Forest Science. A quarterly journal of research and technical progress. [Society of American Foresters.]

Gard. Bull. Singapore—The Gardens' Bulletin. [Singapore; formerly Straits Settlements.]
Gard. Chron. III.—The Gardeners' Chronicle. A weekly illustrated journal of horticulture and allied subjects. Third series. [London.]
Gard. Jour. N. Y. Bot. Gard.—The Garden Journal of the New York Botanical Garden.
Genet. Iber.—Genetica Ibérica. [Consejo Superior de Investigaciones Científicas. Madrid.]
Genetica—Genetica. Nederlands Tijdschrift voor Erfelijkheids- en Afstammingsleer. ['s-Gravenhage.]
Genetics—Genetics. A periodical record of investigations bearing on heredity and variation. [Genetics, Inc.]
Gent. Herb.—Gentes Herbarum. Occasional papers on the kinds of plants. [The Bailey Hortorium, Cornell University.]
Geogr. Rev.—(The) Geographical Review. [The American Geographical Society (of New York).]
Gior. Bot. Ital.—Giornale Botanico Italiano. [Sezione Botanica dei Congressi Scientifici Italiani. Continued as Nuovo Gior. Bot. Ital.]
Great Basin Nat.—The Great Basin Naturalist. [Brigham Young University.]

Hawaii Exp. Sta. Circ.—Hawaii Agricultural Experiment Station. Circular. [Formerly "Circular. University of Hawaii Agricultural Experiment Station."]
Herbertia—Plant Life, Herbertia. [American Plant Life Society. Formerly "Year Book of the American Amaryllis Society." Now issued as a part of "Plant Life."]
Hereditas—Hereditas. Genetisk Arkiv. [Mendelska Sälskapet i Lund.]
Heredity—Heredity. An international journal of genetics. [London & Edinburgh.]
Hilgardia—Hilgardia. A journal of agricultural science. [California Agricultural Experiment Station, Berkeley.]
Holmbergia—Holmbergia. Revista del Centro de Estudiantes del Doctorado en Ciencias Naturales. [Buenos Aires.]
Hook. Ic. V.—Hooker's Icones Plantarum or figures with descriptive characters and remarks of new and rare plants selected from the Kew Herbarium. Fifth Series.
Horticulture—Horticulture. [Horticultural Hall, Boston.]
Hydrobiologia—Hydrobiologia. Acta hydrobiologica, limnologica et protistologica. [Den Haag.]

Ill. Biol. Monogr.—Illinois Biological Monographs. [University of Illinois.]
Inst. Agron. S. Paulo Bol. Téc.—Instituto Agronômico do Estado [de São Paulo], em Campinas. Boletim Técnico.
Inst. Biol. Def. Agr. Rio de Janeiro Bol.—[Ministério da Agricultura, Industria e

Commercio.] Instituto Biologico de Defesa Agricola. Boletim. [Rio de Janeiro. Superseded (with Arch. Jard. Bot. Rio de Janeiro) by Arch. Inst. Biol. Veg. Rio de Janeiro.]

Inst. Bot. Buenos Aires Publ. Téc. II.—Instituto de Botánica. [Biblioteca . . . Buenos Aires.] Publicación Técnica (nueva serie).

Inst. Centr. Foment. Bahia Bol.—Instituto Central de Fomento Econômico da Bahia. Boletim.

Inst. Interam. Ci. Agr. Bol. Téc.—Instituto Interamericano de Ciencias Agrícolas. Boletín Técnico. [Turrialba.]

Inst. Paran. Araucar.—Instituto Paranaense de Botânica. Série Araucarilandia.

Inst. Paran. Bol. Inpabo—Instituto Paranaense de Botânica. [Série] Boletim do Inpabo.

Inst. Paran. Catal. Gên.—Instituto Paranaense de Botânica. [Série] Catálogo e Estatística dos Gêneros Botânicos Fanerogâmicos.

Inst. Paran. Flora—Instituto Paranaense de Botânica. [Série] Flora do Paraná.

Inst. Salubr. Enferm. Trop. Revista—Instituto de Salubridad y Enfermedades Tropicales. Revista. [Mexico.]

Iowa St. Coll. Jour. Sci.—Iowa State College Journal of Science.

Jahrb. Wiss. Bot.—Jahrbücher für Wissenschaftliche Botanik. [Leipzig.]

Jap. Jour. Bot.—[Science Council of Japan.] Japanese Journal of Botany. Transactions and Abstracts.

Jard. Bot. Rio de Janeiro Bol.—[Ministério da Agricultura. Servico Florestal. Secção de Botânica—] Jardim Botânico. Boletim. [Rio de Janeiro.]

Jour. Agr. Res.—Journal of Agricultural Research. [U. S. Department of Agriculture.]

Jour. Agr. Sci.—The Journal of Agricultural Science. [Cambridge, England.]

Jour. Agr. Trop. Bot. Appl.—Journal d'Agriculture Tropicale et de Botanique Appliquée. [Muséum National d'Histoire Naturelle, Paris. Formerly "Revue Internationale de Botanique Appliquée et d'Agriculture Tropicale."]

Jour. Agr. Puerto Rico—The Journal of Agriculture of the University of Puerto Rico.

Jour. Ala. Acad.—The Journal of the Alabama Academy of Science.

Jour. Am. Soc. Agron.—Journal of the American Society of Agronomy. [Continued as "Agronomy Journal."].

Jour. Arnold Arb.—Journal of the Arnold Arboretum, Harvard University.

Jour. Bombay Nat. Hist. Soc.—Journal of the Bombay Natural History Society.

Jour. Bot.—The Journal of Botany, British and Foreign.

Jour. Bot. Soc. S. Afr.—The Journal of the Botanical Society of South Africa.

Jour. Calif. Hort. Soc.—Journal of the California Horticultural Society.

Jour. Ecol.—The Journal of Ecology. [British Ecological Society.]

Jour. Elisha Mitchell Soc.—Journal of the Elisha Mitchell Scientific Society.

Jour. Exp. Bot.—Journal of Experimental Botany. An official organ of the Society for Experimental Biology.

Jour. Fac. Sci. Univ. Tokyo Bot.—Journal of the Faculty of Science, (Imperial) University of Tokyo. Section III. Botany. [Continuation of "Journal of the College of Science. . . ."]

Jour. Forest.—Journal of Forestry. [The Society of American Foresters.]

Jour. Gen. Physiol.—The Journal of General Physiology. [The Rockefeller Institute for Medical Research.]

Jour. Genet.—Journal of Genetics. [Cambridge, England.]

Jour. Hered.—The Journal of Heredity. [The American Genetic Association.]

Jour. Indian Bot. Soc.—The Journal of the Indian Botanical Society. [Formerly "The Journal of Indian Botany."]

Jour. Jap. Bot.—The Journal of Japanese Botany. [Tsumura Laboratory, Tokyo.]

Jour. Linn. Soc. Bot.—The Journal of the Linnean Society of London. Botany.

Jour. Mar. Res.—[Sears Foundation for Marine Research. Brigham Oceanographic Laboratory, Yale University.] Journal of Marine Research.

Jour. N. Y. Bot. Gard.—Journal of the New York Botanical Garden. [Superseded by Gard. Jour. N. Y. Bot. Gard.]

Jour. Polynes. Soc.—Journal of the Polynesian Society. Containing the Transactions

and Proceedings of the Society. (Devoted to the study of the native peoples of Polynesia and related oceanic regions.)

Jour. Roy. Hort. Soc.—Journal of the Royal Horticultural Society. [London.]

Jour. S. Afr. Bot.—The Journal of South African Botany. [National Botanic Gardens of South Africa, Kirstenbosch.]

Jour. Sci. Lab. Denison Univ.—Journal of the Scientific Laboratories of Denison University.

Jour. Soc. Bibliogr. Nat. Hist.—The Journal of the Society for the Bibliography of Natural History. [British Museum.]

Jour. Tenn. Acad.—Journal of the Tennessee Academy of Science.

Jour. Wash. Acad.—Journal of the Washington [D.C.] Academy of Sciences.

Kew Bull.—[Royal Botanic Gardens, Kew.] Kew Bulletin. [Formerly "Bulletin of Miscellaneous Information."]

Kolon. Inst. Amsterdam Meded.—Vereeniging Koloniaal Instituut te Amsterdam. Mededeeling. Afdeeling Handelsmuseum.

Lasca Leaves—Lasca Leaves. Quarterly Publication of the Southern California Horticultural Institute and the California Arboretum Foundation, Inc.

Leafl. West. Bot.—Leaflets of Western Botany. [San Francisco.]

Lejeunia Bull.—Lejeunia. Revue de Botanique—Bulletin. [Formerly subtitled "Bulletin des Botanistes Liégois."]

Lejeunia Mém.—Lejeunia. Revue de Botanique. Mémoire. [Liège.]

Lilloa—Lilloa. Revista de Botânica. [Universidad Nacional de Tucumán. Instituto "Miguel Lillo."]

Lloydia—Lloydia. A quarterly journal of biological science. [Lloyd Library and Museum.]

Los Angeles Mus. Contr. Sci.—Los Angeles County Museum Contributions in Science.

Lunds Univ. Årsskr. II. Sect. 2.—Lunds Universitets Årsskrift. N[ya] F[ölg]. Afd[elning] 2.

Madj. Ilmu Alam Indon.—Madjalah Ilmu Alam untuk Indonesia. (Indonesian Journal for Natural Science.) [Continuation of Chron. Nat.]

Madroño—Madroño, a West American journal of botany. [California Botanical Society.]

Malpighia—Malpighia. Rassegna mensile (mensuale) di botanica.

Maria Moors Cabot Found. Publ.—Maria Moors Cabot Foundation. Publication. [Bussey Institute of Harvard University.]

Meddel. Grønl.—Meddelelser om Grønland. [Kommisionen for Videnskabelige Undersøgelser i Grønland. Kjøbenhavn.]

Meded. Bot. Mus. Utrecht—Mededeelingen van het Botanisch Museum en Herbarium van de Rijksuniversiteit te Utrecht.

Mem. Acad. Barcelona III.—Memorias de la Real Academia de Ciencias y Artes de Barcelona. Tercera época.

Mem. Acad. Mexico—Memorias y Revista de la Academia Nacional de Ciencias ("Antonio Alzate"). [Mexico.]

Mém. Acad. St.-Pétersb. VIII.—[Zapiski Imperatorskoi Akademii Nauk po Fiziko-Matematicheskomi Otdeleniiu.] Mémoires de l'Académie Impériale des Sciences de St.-Pétersbourg. Classe des Sciences Physiques et Mathématiques. VIII[e] série. [Title and subtitle differ in different series. Series VII is under Akademiia Nauk SSSR.]

Mem. Boston Soc. Nat. Hist.—Memoirs of the Boston Society of Natural History.

Mem. Gray Herb.—Memoirs of the Gray Herbarium of Harvard University.

Mem. Cornell Univ. Exp. Sta.—Memoir. Cornell University. Agricultural Experiment Station.

Mem. Inst. Oswaldo Cruz—Memórias do Instituto Oswaldo Cruz. [Rio de Janeiro.]

Mém. Jard. Bot. Montréal—Mémoires du Jardin Botanique de Montréal. Memoirs of the Montreal Botanical Garden. [Mostly reprinted from other serials.]

Mem. Montreal Bot. Gard.—Memoirs of the Montreal Botanic Garden. [Mostly reprinted from other serials.]

Mem. Mus. Entre Ríos—Memorias del Museo de Entre Ríos. [Argentina. Formerly "Las Memorias del Museo de Paraná."]

Mem. N. Y. Bot. Gard.—Memoirs of the New York Botanical Garden.

Mem. So. Calif. Acad.—Memoirs of the Southern California Academy of Sciences.

Mem. Soc. Cub. Hist. Nat.—Memorias de la Sociedad Cubana de Historia Natural "Felipe Poey."

Mem. Soc. Fauna Fl. Fenn.—Memoranda Societatis pro Fauna et Flora Fennica.

Mém. Soc. Vaud. Sci. Nat.—Mémoires de la Société Vaudoise des Sciences Naturelles. [Lausanne.]

Mem. Torrey Club—Memoirs of the Torrey Botanical Club.

Minn. Bot. Stud.—[Geological and Natural History Survey of Minnesota.] Minnesota Botanical Studies. Reports of the Survey and Bulletin of the Department. Botanical Series. [Title and subtitle vary, and the two have differently numbered volumes. The series continued as Minn. Stud. Pl. Sci.]

Minn. Stud. Pl. Sci.—[Research Publications of the University of Minnesota. Studies in the Biological Sciences.] Minnesota Studies in Plant Science. (Continuation of Minnesota Botanical Studies.)

Missouri Bot. Gard. Bull.—Missouri Botanical Garden Bulletin.

Mitt. Bot. Mus. Zürich—Mitteilungen aus dem Botanischen Museum der Universität Zürich.

Mitt. Bot. Staatssam. München—Mitteilungen der Botanischen Staatssamlung, München.

Mitt. Deutsch. Dendr. Ges.—Mitteilungen der Deutschen Dendrologischen Gesellschaft. Jahrbuch.

Mitt. Thür. Bot. Ges.—Schriften der Thüringischen Landesarbeitsgemeinschaft für Heilpflanzenkunde und Heilpflanzenbeschaffung in Weimar und Mitteilungen der Thüringischen Botanischen Gesellschaft (ehemals Thüringischer Botanischer Verein).

Monde Pl.—Le Monde des Plantes. Intermédiaire des botanistes. Supplément aux bulletins de plusieurs sociétés savantes.

Monogr. Inst. Estud. Geogr. Tucumán—Monografías del Instituto de Estudios Geográficos. [Universidad Nacional de Tucumán, Facultad de Filosofía y Letras.]

Morris Arb. Bull.—Morris Arboretum Bulletin. [University of Pennsylvania. Formerly "Arboretum Bulletin of the Associates."]

Mus. Nahuel Huapí Anal.—[San Carlos de Bariloche.] Museo Nahuel Huapí. Anales. [Ministerio de Obras Públicas de la Nación. Administración General de Parques Nacionales y Turismo.]

Mutisia—Mutisia (Acta Botanica Colombiana). [Bogotá.]

Mycologia—Mycologia. Official organ of the Mycological Society of America. [The New York Botanical Garden.]

N. Am. Fl. II.—North American Flora. Series II. [The New York Botanical Garden.]

N. H. Acad. Bull.—New Hampshire Academy of Science. Bulletin.

Nat. Appl. Sci. Bull.—Natural and Applied Science Bulletin. [University of the Philippines.]

Nat. Canad.—Le Naturaliste Canadien. [L'Université Laval, Québec.]

Nat. Hist. Bull. Hawaii Nat. Park—Natural History Bulletin. Hawaii National Park. [Mimeogr.]

Nat. Hist. Misc.—Natural History Miscellanea. [Chicago Academy of Sciences.]

Natl. Cact. & Succ. Jour.—The National Cactus and Succulent Journal. Official organ of the National Cactus and Succulent Society. [England.]

Natl. Hort. Mag.—The National Horticultural Magazine. Journal of the American Horticultural Society.

Natl. Mus. Canada Bull.—[Canada. Department of Northern Affairs and Natural Re-

sources. (Also as Department of Mines and Resources.)] National Museum of Canada. Bulletin.

Natura Buenos Aires—[Ministerio de Agricultura y Ganadería de la Nación.] Natura. Organo oficial de la Administración General de Parques Nacionales. [Buenos Aires.]

Natura S. Paulo—Natura. Instituto Kurihara da Ciéncia Natural Brasileira. [São Paulo. Mostly in Japanese.]

Nature—Nature. A weekly journal of science. [London.]

Nature Paris—La nature. Revue des sciences et de leurs applications à l'art et à l'industrie. [Paris.]

Natuurk. Tijd. Ned. Ind.—[See Natuurw. Tijd. Ned. Ind.]

Natuurw. Tijd. Ned. Ind.—Natuurwetenschappelijk Tijdschrift voor Nederlandsch Indië. [Formerly "Natuurkundig Tijdschrift voor Nederlandsch Indië." Koninklijke Naturkundige Vereeniging in Nederlandsch Indie. Continued as Chron. Nat.]

New Phytol.—The New Phytologist. [Oxford.]

Northw. Nat.—Northwest Naturalist (Puget Sound Academy of Science). [Seattle.]

Northw. Sci.—Northwest Science. Official publication of The Northwest Scientific Association.

Not. Nat.—Notulae Naturae of the Academy of Natural Sciences of Philadelphia.

Not. Syst. Leningrad—Notulae Systematicae ex Herbario Horti Botanici U.S.S.R. Botanicheskie Materiali Gerbariia Glavnova Botanicheskovo Sada S. S. S. R.

Not. Syst. Paris—[Muséum National d'Histoire Naturelle.] Notulae Systematicae. [Paris.]

Notas Mus. La Plata Bot.—[Ministerio de Educación de la Nación. Universidad Nacional de La Plata (Eva Perón).* Facultad de Ciencias Naturales y Museo.] Notas del Museo. Botánica.

Nova Acta Acad. Leop.-Carol.—Nova Acta (Leopoldina) Academiae Caesareae Leopoldino-Carolinae Naturae Curiosorum. [Title also in German, in some years only in German: Verh. Leop.-Carol. Akad. Name of the Academy has varied greatly; until 1922 as Leopoldinisch-Carolinische Deutsche Akademie der Naturforscher; more recently as K. Deutsche Akademie der Naturforscher zu Halle. Publications appeared under several successive titles, variously cited.]

Nuovo Gior. Bot. Ital.—Nuovo Giornale Botanico Italiano. (Nuova serie.) [Società Botanica Italiana. Continuation of Gior. Bot. Ital.]

Nytt Mag. Naturvid.—Nytt Magasin for Naturvidenskapene. [Oslo.]

Occ. Pap. Bishop Mus.—Occasional Papers of the Bernice Pauahi Bishop Museum of Polynesian Ethnology and Natural History.

Occ. Pap. Fairchild Trop. Gard.—Occasional Paper. Fairchild Tropical Garden.

Österr. Bot. Zeitschr.—Österreichische Botanische Zeitschrift. [Wien. Vols. 92, 93 (1943, 1944) were titled "Wiener Botanische Zeitschrift."]

Ohio Jour. Sci.—The Ohio Journal of Science. [Ohio State University and Ohio Academy of Science. Continuation of Ohio Nat.]

Ohio Nat.—The Ohio Naturalist and Journal of Science. Official organ of The Biological Club of the Ohio State University and of The Ohio Academy of Science. [Continued as Ohio Jour. Sci.]

Oikos—Oikos. Acta oecologica scandinavica. [Copenhagen.]

Op. Bot.—Opera Botanica a Societate Botanica Lundensi in Supplementum Seriei "Botaniska Notiser" edita. [Continuation of "Botaniska Notiser. Supplement."]

Orchid Dig.—The Orchid Digest. [Berkeley.]

Orchid Jour.—The Orchid Journal. An international review of orchidology. [Pasadena.]

Ore. Monogr. Bot.—Oregon State Monographs. Studies in Botany. [Oregon State College.]

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* For a brief period the name La Plata was changed to Eva Perón, and serials issued in that city underwent a corresponding change of title.

Org. Sci. Res. Indon. Bull.—[(Organisatie voor Natuurwetenschappelijk Onderzoek).] Organization for Scientific Research in Indonesia. Bulletin. [Djakarta.]
Orquídea Mexico—Orquídea. Organo oficial de la Sociedad Mexicana "Amigos de las Orquídeas."
Orquídea Rio de Janeiro—Orquídea. [Rio de Janeiro.]
Oxford Forestry Mem.—Oxford Forestry Memoirs. [England.]

Pacif. Discov.—Pacific Discovery. [California Academy of Sciences.]
Pacif. Sci.—Pacific Science; a quarterly devoted to the biological and physical sciences of the Pacific region. [University of Hawaii.]
Palaeobotanist—The Palaeobotanist. [Birbal Sahni Institute of Palaeobotany.]
Palaeontographica—Palaeontographica. Beiträge zur Naturgeschichte der Vorzeit. [Stuttgart.]
Pap. Mich. Acad. I.—Papers of the Michigan Academy of Science, Arts and Letters. Part I. Natural science. [Formerly "Part I. Botany and forestry."]
Pap. Peabody Found. Archaeol.—Papers of the Robert S. Peabody Foundation for Archaeology.
Pap. Tortugas Lab.—Papers from the Tortugas Laboratory of the Carnegie Institution of Washington [D. C.].
Philip. Agr. Rev.—The Philippine Agricultural Review. [Bureau of Agriculture, Manila.]
Philip. Dep. Agr. Comm. Tech. Bull.—[Republic of the Philippines. Department of Agriculture and Commerce.] Technical Bulletin.
Philip. Jour. Sci.—The Philippine Journal of Science. [Institute of Science and Technology, Manila.]
Philip. Orchid Rev.—Philippine Orchid Review. [The Philippine Orchid Society.]
Philos. Trans. Roy. Soc. London B.—Philosophical Transactions of the Royal Society of London. Series B. Biological Sciences.
Physiol. Plant.—Physiologia Plantarum. [Societas Physiologiae Plantarum Scandinavica.]
Physis—Physis. Revista de la Sociedad Argentina de Ciencias Naturales.
Phytologia—Phytologia. Designed to expedite botanical publication. [Harold Norman Moldenke, Yonkers.]
Phytomorphology—Phytomorphology. An international journal of plant morphology. Official organ of The International Society of Plant Morphologists. [University of Delhi.]
Phyton Austria—Phyton. Annales Rei Botanicae. [Horn, Austria.]
Phyton Buenos Aires—ΦYTON. Revista Internacional de Botánica Experimental. International Journal of Experimental Botany. [Buenos Aires.]
Phytopathology—Phytopathology. An international journal. Official organ of The American Phytopathological Society.
Pl. Life—Plant Life. [The American Plant Life Society. See also Herbertia.]
Pl. Physiol.—Plant Physiology. [The American Society of Plant Physiologists.]
Pl. Sci. Bull.—Plant Science Bulletin. A publication of the Botanical Society of America, Inc.
Planta—Planta. Archiv für wissenschaftliche Botanik. [Berlin.]
Plateau—Plateau. A quarterly. [Northern Arizona Society of Science and Art, Museum of Northern Arizona, Flagstaff.]
Polsk. Towarz. Bot. Monogr.—Polskie Towarzystwo Botaniczne. Monographiae Botanicae. [Societas Botanicorum Poloniae.]
Portug. Acta Biol. A.—Portugaliae Acta Biologica (Series A). [Instituto Botánico da Faculdade de Ciências de Lisboa; Laboratório de Patologia Vegetal "Verissimo de Almeida"; Sociedade de Ciências Naturais.]
Principes—Principes. Journal of the Palm Society. [Daytona Beach.]
Proc. Acad. Phila.—Proceedings of the Academy of Natural Sciences of Philadelphia.
Proc. Am. Acad.—Proceedings of the American Academy of Arts and Sciences. [Boston.]

Proc. Am. Philos. Soc.—Proceedings of the American Philosophical Society held at Philadelphia for promoting useful knowledge.

Proc. Am. Soc. Hort. Sci.—Proceedings of the American Society for Horticultural Science.

Proc. Ark. Acad.—Proceedings of the Arkansas Academy of Science.

Proc. Biol. Soc. Wash.—Proceedings of the Biological Society of Washington [D. C.].

Proc. Calif. Acad.—Proceedings of the California Academy of Sciences.

Proc. Indian Acad. B.—(Supplement to the "Proceedings of the Indian Academy of Sciences.") Proceedings of the Indian Academy of Sciences. Section B.

Proc. Indiana Acad.—Proceedings of the Indiana Academy of Science.

Proc. Iowa Acad.—Proceedings of the Iowa Academy of Science.

Proc. La. Acad.—The Proceedings of the Louisiana Academy of Sciences.

Proc. Linn. Soc.—Proceedings of the Linnean Society of London.

Proc. Mont. Acad.—Proceedings of the Montana Academy of Sciences.

Proc. Nat. Sci. Assoc. Staten Is.—Proceedings of the Natural Science Association of Staten Island. [Superseded by Proc. Staten Is. Inst.]

Proc. Natl. Acad. U. S.—Proceedings of the National Academy of the United States of America.

Proc. Natl. Inst. India—Proceedings of the National Institute of Sciences of India. [New Delhi.]

Proc. Nova Scot. Inst.—(The) Proceedings (and Transactions) of the Nova Scotian Institute of Science.

Proc. Okla. Acad.—Proceedings of the Oklahoma Academy of Science.

Proc. Pa. Acad.—Proceedings of the Pennsylvania Academy of Science.

Proc. Roy. Dublin Soc.—The Scientific Proceedings of the Royal Dublin Society. New Series.

Proc. Roy. Soc. Edinb. B.—Proceedings of the Royal Society of Edinburgh. Section B (Biology).

Proc. Roy. Soc. London B.—Proceedings of the Royal Society of London. Series B—Biological Sciences.

Proc. Staten Is. Inst.—Proceedings of the Staten Island Institute (Association) of Arts and Sciences.

Proc. Trans. Roy. Soc. Canada—Proceedings and Transactions of the Royal Society of Canada. (Mémoires et Comptes Rendus de la Société Royale du Canada.)

Proc. U. S. Natl. Mus.—[Smithsonian Institution. United States National Museum.] Proceedings of the United States National Museum.

Proc. W. Va. Acad.—Proceedings of the West Virginia Academy of Science. West Virginia University Bulletin.

Publ. Field Mus. Bot.—Publications of (the) Field (Columbian) Museum (of Natural History). Botanical Series. [Title varies. Superseded by "Fieldiana."]

Publ. Inst. Agron. Congo Belge Sci.—Publication de l'Institut National pour l'Étude Agronomique du Congo Belge (I. N. E. A. C.). Série scientifique.

Publ. Inst. Agron. Congo Belge Tech.—Publication de l'Institut National pour l'Étude Agronomique du Congo Belge (I. N. E. A. C.). Série technique.

Publ. Mus. Hist. Nat. Lima Bot.—Publicaciones del Museo de Historia Natural "Javier Prado." [Universidad Nacional Mayor de San Marcos.] Botánica, Serie B. [Lima.]

Publ. Puget Sound Biol. Sta.—Publications. Puget Sound Biological Station. [University of Washington.]

Publ. Univ. S. Domingo—Publicaciones de la Universidad de Santo Domingo.

Quart. Jour. Fla. Acad.—Quarterly Journal of the Florida Academy of Sciences. [Formerly "Proceedings."]

Quart. Jour. Forest.—Quarterly Journal of Forestry. [The Royal English Arboricultural Society.]

Quart. Jour. Taiwan Mus.—Quarterly Journal of the Taiwan Museum.

Quart. Rev. Biol.—The Quarterly Review of Biology. [American Institute of Biological Sciences.]

Rec. Trav. Bot. Néerl.—Recueil des Travaux Botaniques Néerlandais. [Société Botanique Royale Néerlandaise. Superseded by "Acta Botanica Neerlandica."]

Reinwardtia—Reinwardtia being a continuation of the Bulletin du Jardin Botanique de Buitenzorg (Bulletin of the Botanic Gardens, Buitenzorg).

Relat. Inst. Bot. S. Paulo D.—[Secretaria da Agricultura—São Paulo—Brasil.] Relatório Annual do Instituto de Botânica (ex Departamento de Botânica do Estado) (Publicação da Serie "D").

Rep. Mich. Acad.—Annual Report (of) the Michigan Academy of Science, Arts, and Letters.

Rep. Smithson. Inst.—Annual Report of the Board of Regents of the Smithsonian Institution.

Repert. Sp. Nov.—Feddes Repertorium Specierum Novarum Regni Vegetabilis. [Berlin.]

Repert. Sp. Nov. Beih.—Feddes Repertorium Specierum Novarum. Beiheft. [Berlin.]

Res. Bull. Exp. Sta. Univ. Wis.—Research Bulletin. (Agricultural Experiment Station of the) University of Wisconsin.

Res. Stud. St. Coll. Wash.—Research Studies of the State College of Washington.

Resum. Genet.—Resumptio Genetica. [Supplement to Genetica. See also Bibliogr. Genet. 's-Gravenhage.]

Revista Acad. Colomb.—Revista de la Academia Colombiana de Ciencias Exactas, Fisicas y Naturales. (Correspondiente de la Española). [Ministerio de Educación Nacional.]

Revista Agr. Cochabamba—[Publicaciones de la Universidad Mayor de San Simon.] Revista de Agricultura. Organo oficial de la Facultad de Ciencias Agronómicas de la Universidad de Cochabamba [Bolivia].

Revista Argent. Agron.—Revista Argentina de Agronomía. [Sociedad Argentina de Agronomía.]

Revista Bras. Geogr.—Revista Brasileira de Geografia. [Instituto Brasileiro de Geografia e Estatística.]

Revista Chil. Hist. Geogr.—Revista Chilena de Historia y Geografía. [Sociedad Chilena de Historia y Geografía. Archivo Nacional.]

Revista Chil. Hist. Nat.—Revista Chilena de Historia Natural. Publicación ilustrada dedicada al fomento y cultivo de las ciencias naturales en Chile. [Santiago de Chile.]

Revista Fac. Agr. Venezuela—Revista de la Facultad de Agricultura. Organo oficial de la Facultad de Agricultura de la Universidad Central de Venezuela.

Revista Fac. Agron. Medellin—Revista. Facultad Nacional de Agronomía. [Medellin.]

Revista Inst. Invest. Ci. Nat. Buenos Aires Bot.—[Ministerio de Educación de la Nación. Dirección General de Cultura.] Revista del Instituto Nacional de Investigación de las Ciencias Naturales anexo al Museo Argentino de Ciencias Naturales "Bernardino Rivadavia." Ciéncias botánicas.

Revista Invest. Agr. Buenos Aires—Revista de Investigaciones Agrícolas. [Dirección General de Investigaciones del Ministerio de Agricultura (y Ganaderia) (de la Nación).]

Revista Mus. La Plata Bot.—[Universidad Nacional de La Plata. Instituto del Museo.] Revista del Museo de La Plata. Sección Botánica. (Nueva serie.)

Revista Soc. Cub. Bot.—Revista de la Sociedad Cubana de Botánica. [Jardin Botánico de la Universidad de la Habana.]

Revista Soc. Mex. Hist. Nat.—Revista de la Sociedad Mexicana de Historia Natural.

Revista Sudam. Bot.—Revista Sudamericana de Botánica. [Asociación Sudamericana de Botánica. Montevideo.]

Revista Univ. Cuzco—Revista Universitaria. [Universidad Nacional del Cuzco.]

Revue Algol. II.—Revue Algologique. Nouvelle série. [Centre National de la Recherche Scientifique. Muséum National d'Histoire Naturelle, Laboratoire de Cryptogamie. Paris.]

Revue Bot. Appl. Agr. Trop.—Revue Internationale de Botanique Appliquée et d'Agriculture Tropicale. [Muséum National d'Histoire Naturelle. Laboratoire d'Agronomie Coloniale Paris. Superseded by Jour. Agr. Trop. Bot. Appl.]

Revue Bryol.—Revue Bryologique. [Paris. Continued as Rev. Bryol. Lichénol.]
Revue Bryol. Lichénol.—Revue Bryologique et Lichénologique. Nouvelle série. [Second series of "Revue Bryologique." Centre National de la Recherche Scientifique. Muséum National d'Histoire Naturelle, Laboratoire de Cryptogamie. Paris.]
Revue Canad. Biol.—Revue Canadienne de Biologie. [Université de Montréal.]
Revue Oka—Revue d'Oka. [Institut (Agricole) d'Oka, Université de Montréal.]
Revue Gén. Bot.—Revue Général de Botanique. [Centre National de la Recherche Scientifique. Paris.]
Revue Mycol. Paris—Revue de Mycologie. [Laboratoire de Cryptogamie du Muséum National d'Histoire Naturelle, Paris.]
Revue Mycol. Toulouse—Revue Mycologique. Recueil trimestriel illustré, consacré à l'étude des champignons et des lichens. [Toulouse.]
Rhodora—Rhodora. Journal of the New England Botanical Club.
Rodriguésia—[Ministério da Agricultura.] Rodriguésia. Revista do Jardim Botânico. [Rio de Janeiro.]

S. Paulo Inst. Bot. Publ. D.—[Secretario da Agricultura, Indústria e Comércio, São Paulo—Brasil.] Instituto de Botânica (Publicação da série "D").
Sargentia—Sargentia. A continuation of the Contributions from the Arnold Arboretum of Harvard University.
Sci. Month.—The Scientific Monthly. [American Association for the Advancement of Science. In 1958 combined with "Science."]
Science—Science. [American Association for the Advancement of Science.]
Serol. Mus. Bull.—The Serological Museum. Bulletin. [Rutgers University.]
Sierra Club Bull.—The Sierra Club Bulletin.
Sitz-ber. Akad. Berlin—Sitzungsberichte der (Königlich-) Preussischen Akademie der Wissenschaften (zu Berlin).
Sitz-ber. Akad. München II.—Sitzungsberichte der mathematisch-physikalischen Classe der k[öniglichen] b[ayerischen] Akademie der Wissenschaften zu München. [The earlier series was not divided into classes.]
Sitz-ber. Akad. Wien.—[See Akad. Wien Sitz-ber.]
Skr. Vid.-Akad. Oslo—Skrifter utgitt av det Norske Videnskaps-Akademi i Oslo. I. Matematisk-Naturvidenskapelig Klasse.
Smithson. Misc. Collect.—Smithsonian Miscellaneous Collections. [Smithsonian Institution.]
Soc. Bot. Méx. Bol.—Sociedad Botánica de México. Boletín. [Continued as "Boletín de la Sociedad Botánica de México."]
Soc. Zool.-Bot. Vanamo Ann. Bot.—Societas Zoologico-Botanica Vanamo (Summalainen eläcin-ja Kasvitieteellinen seura Vanamo). Kaovitieteellisië. Annales botanici.
Southw. Nat.—The Southwestern Naturalist. [The Southwestern Association of Naturalists.]
Spec. Publ. Brit. Col. Prov. Mus.—Special Publication. British Columbia Provincial Museum, Department of Education.
Stain Tech.—Stain Technology. A journal for microtechnic and histochemistry. [Biological Stain Commission.]
Stanford Univ. Publ. Biol.—Stanford University Publications. University Series. Biological Sciences.
Stud. Bot. Cechosl.—Studia Botanica Cechoslovaca. [Societatis Botanicae Cechoslovacae.]
Suel. Ecuat.—Suelos Ecuatoriales. [Sociedad Colombiana de la Ciencia del Suelo.]
Sukkulentenkunde—Sukkulentenkunde. Jahrbücher der Schweizerischen Kakteen-Gesellschaft.
Sunyatsenia—Sunyatsenia. [Botanical Institute, College of Science, Sun Yatsen University.]
Sv. Bot. Tidskr.—Svensk Botanisk Tidskrift. [Svenska Botaniska Föreningen.]
Sv. Vet-akad. Årsb.—Kungl. Svenska Vetenskapsakademiens Arsbok.
Sv. Vet-akad. Handl. III.—Kungliga Svenska Vetenskapsakademiens Handlingar. Tredje serien.

Symb. Bot. Upsal.—Symbolae Botanicae Upsalienses. Arbeten från Botaniska Institutionerna i Uppsala.
Symp. Soc. Exp. Biol.—Symposia of the Society for Experimental Biology.

Tech. Bull. Ariz. Exp. Sta.—Technical Bulletin. University of Arizona. College of Agriculture. Agricultural Experiment Station.
Tech. Bull. U. S. Dep. Agr.—Technical Bulletin. United States Department of Agriculture.
Torreya—Torreya. A (monthly) quarterly journal of botanical notes and news. [Since 1946 in Bull. Torrey Club.]
Trans. Acad. St. Louis—Transactions of the Academy of Science of St. Louis.
Trans. Am. Micr. Soc.—Transactions of the American Microscopical Society.
Trans. Am. Philos. Soc.—Transactions of the American Philosophical Society held at Philadelphia for promoting useful knowledge.
Trans. Brit. Bryol. Soc.—Transactions of the British Bryological Society.
Trans. Canad. Inst.—Transactions of the (Royal) Canadian Institute.
Trans. Ill. Acad.—Transactions of the Illinois State Academy of Science.
Trans. Kan. Acad.—Transactions of the Kansas Academy of Science.
Trans. Linn. Soc. III.—The Transactions of the Linnean Society of London. Ser. III.
Trans. Natl. Inst. India—Transactions of the National Institute of Sciences of India. [New Delhi.]
Trans. Proc. Bot. Soc. Edinb.—Transactions and Proceedings of the Botanical Society of Edinburgh.
Trans. Roy. Soc. Edinb.—Transactions of the Royal Society of Edinburgh.
Trans. Wis. Acad.—Transactions of the Wisconsin Academy of Sciences, Arts and Letters.
Trav. Biol. Inst. Carnoy—Travaux Biologiques de l'Institut J. B. Carnoy. [Louvain.]
Trav. Lab. Forestier Toulouse—Travaux du Laboratoire Forestier de Toulouse. [Publiés . . . avec le concours du Centre National de la Recherche Scientifique.]
Trillia—Trillia. Proceedings of the Botanical Society of Western Pennsylvania.
Trop. Woods—[Yale University School of Forestry.] Tropical Woods.

U. S. Dep. Agr. Bibliogr. Bull.—United States Department of Agriculture. Bibliographical Bulletin.
U. S. Dep. Agr. Misc. Publ.—United States Department of Agriculture. Miscellaneous Publication.
U. S. Nat. Mus. Rep.—The United States National Museum. Annual Report. [Smithsonian Institution.]
Univ. Antioquia—Universidad de Antioquia. [Medellin. No other title designates this serial.]
Univ. Appl. Sci. Dep. Agr. Rep. Reykjavík—Atvinnudeild Háskólans—University of Applied Sciences. Rit Landbúsoardeildar, B-flokkur. Department of Agriculture, Reports, Series B. Reykjavík.
Univ. Ariz. Biol. Sci. Bull.—University of Arizona Bulletin. Biological Science Bulletin. [Includes "Laboratory of Tree-Ring Research Bulletin"?]
Univ. Bergen Årb. Naturv.—Universitetet i Bergen. Årbok. Naturvitenskapelig Rekke.
Univ. Bombay Bot. Mem.—University of Bombay. Botanical Memoirs.
Univ. Calif. Publ. Bot.—University of California Publications in Botany.
Univ. Colo. Stud. D.—The University of Colorado Studies. Series D. Physical and Biological Sciences.
Univ. Ecuador Anal.—Universidad Central del Ecuador. Anales.
Univ. Iowa Stud. Nat. Hist.—State University of Iowa. Studies in Natural History.
Univ. Kan. Sci. Bull.—University of Kansas Science Bulletin.
Univ. Ore. Monogr. Bot.—University of Oregon Monographs. Studies in Botany.
Univ. S. Domingo Anal.—Universidad de Santo Domingo. Anales. [Also as "Anales de la Universidad. . ."]

Univ. S. Paulo Fa . Filos. Ci. Letr. Bol. Bot.—Universidade de São Paulo. Faculdade de Filosofia, Ciências e Letras. Boletim. Botánica.
Univ. Wash. Publ. Biol.—University of Washington [State] Publications in Biology.
Univ. Wyo. Publ.—University of Wyoming Publications. [Continuation of "University of Wyoming Publications in Science."]
Uppsala Univ. Årsskr.—Uppsala Universitets Årsskrift. (Recueil de travaux publié par l'Université d'Uppsala.)
Uredineana—Uredineana. Recueil d'études systématiques et biologiques sur les urédinées du globe. [Paris.]

Va. Jour. Sci.—The Virginia Journal of Science. [The Virginia Academy of Science.]
Vegetatio—Vegetatio. Acta geobotanica. Revue Internationale de Phytosociologie [this subtitle in 5 languages]. Organe officiel de l'Association Internationale de Phytosociologie. [Den Haag.]
Ver. Ind. Inst. Meded.—Koninklijke Vereeniging Indisch Instituut (Royal Institute for the Indies). Amsterdam. Mededeeling. Afdeeling Tropische Producten (vorheen Handelsmuseum).
Verh. Zool.-Bot. Ges. Wien—Verhandlungen der Zoologisch-Botanischen Gesellschaft in Wien.
Verh. Leop.-Carol. Akad.—Verhandlungen der Leopoldinisch-Carolinischen Deutschen Akademie der Naturforscher. [See Nova Acta Acad. Leop.-Carol.]
Verh. Naturf. Ges. Basel—Verhandlungen der Naturforschenden Gesellschaft in Basel.
Veröff. Geobot. Inst. Zürich—Veröffentlichungen des Geobotanischen Institutes Rübel in Zürich.
Vict. Nat.—The Victorian Naturalist. A monthly journal of natural history. [The Field Naturalists Club of Victoria, Inc.]
Viert. Naturf. Ges. Zürich—Vierteljahrsschrift der Naturforschenden Gesellschaft in Zürich.

Wasmann Collect.—The Wasmann Collector. A journal of biology. [University of San Francisco. Continued as "The Wasmann Journal of Biology."]
Wasmann Jour. Biol.—The Wasmann Journal of Biology. [University of San Francisco. Continuation of "The Wasmann Collector."]
Watsonia—Watsonia. Journal of the Botanical Society of the British Isles.
Wien Bot. Zeitschr.—Wiener Botanische Zeitschrift. [See Österr. Bot. Zeitschr.]
Wild Flower—Wild Flower. [The Wild Flower Preservation Society, Inc.]
Wrightia—Wrightia. A botanical journal. [Southern Methodist University.]

Yearb. Rhod. Assoc.—Year Book of the Rhododendron Association. [Great Britain.]
Yearb. U. S. Dep. Agr.—The Yearbook of Agriculture. United States Department of Agriculture.

Zeitschr. Abst. Vererb.—Zeitschrift für Induktive Abstammungs- und Vererbungslehre. [Berlin.]
Zeitschr. Bot.—Zeitschrift für Botanik. [Jena.]
Zeitschr. Pflanzenkr.—Zeitschrift für Pflanzenkrankheiten (Pflanzenpathologie) und Pflanzenschutz. [Stuttgart. Early volumes "Unter Mitwirkung der internationalen phytopathologischen Kommission." Title has varied.]

BULLETIN OF THE TORREY BOTANICAL CLUB

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INDEX TO AMERICAN BOTANICAL LITERATURE

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LAZELLA SCHWARTEN

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TAXONOMY, PHYLOGENY AND FLORISTICS

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